



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

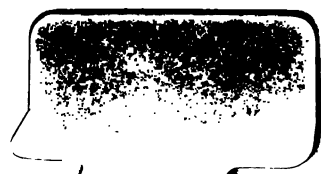
We also ask that you:

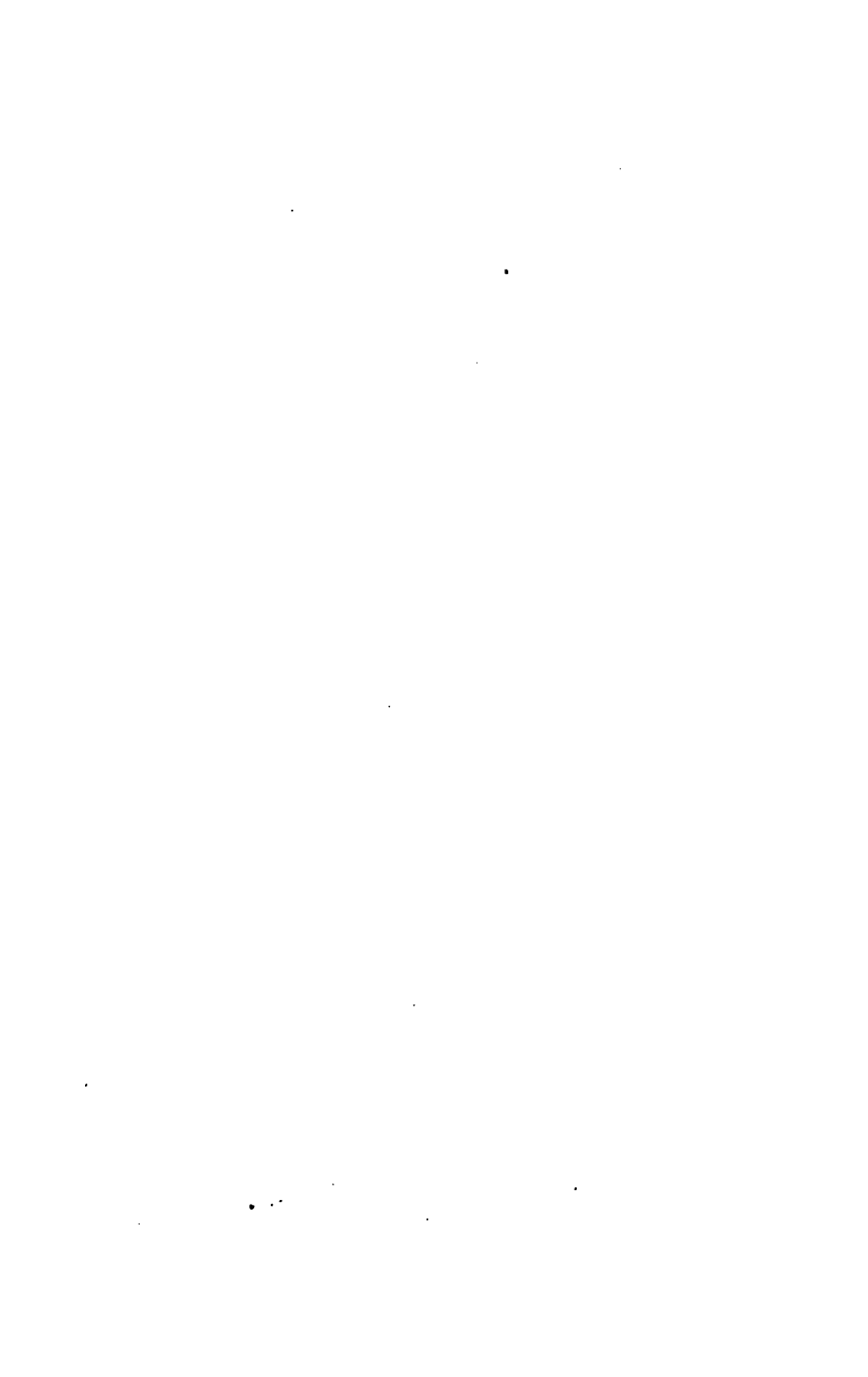
- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>







CONVERSATIONS
ON
CHEMISTRY.
VOL. II.

LONDON:
SPOTTISWOODES and SHAW,
New-Street-Square.

CONVERSATIONS
ON
CHEMISTRY;

IN WHICH
The Elements of that Science
ARE
FAMILIARLY EXPLAINED
AND
ILLUSTRATED BY EXPERIMENTS.

BY MRS. MARCET.

THE SIXTEENTH EDITION, REVISED AND CORRECTED.

IN TWO VOLUMES.
VOL. II.—ON COMPOUND BODIES.

LONDON:
LONGMAN, BROWN, GREEN, AND LONGMANS,
1853.



145. c. 37.

CONTENTS

OF

THE SECOND VOLUME.

~~~~~

ON COMPOUND BODIES.

~~~~~

CONVERSATION XII.

ON THE ATTRACTION OF COMPOSITION

Page
1

Of the Laws which regulate the Phenomena of the Attraction of Composition :—1. It takes place only between Bodies of a different Nature.—2. Between the most minute Particles only.—3. Between, two, three, four or more Bodies.—Of Compound or Neutral Salts.—4. Produces a Change of Temperature.—5. The Properties which characterise Bodies in their separate State destroyed by Combination.—6. The Force of Attraction estimated by that which is required for the Separation of the Constituents.—7. Bodies have amongst themselves different Degrees of Attraction.—Of simple elective and double elective Attractions.—Of quiescent and divellent Forces.—Law of definite Proportions.—Atomic Theory.—Account of Diamorphism or Isomerism.—Decomposition of Salts by Voltaic Electricity.

CONVERSATION XIII.

ON ALKALIES,

Page
25

Of the Composition and general Properties of the Alkalies.—Of Lithion.—Of Potash; Manner of preparing it.—Pearl-ash.—Soap.—Carbonate of Potash.—Of Glass.—Of Nitrate of Potash, or Saltpetre.—Effect of Alkalies on Vegetable Colours.—Of Soda.—Of Ammonia or Volatile Alkali.—Muriate of Ammonia.—Ammoniacal Gas.—Composition of Ammonia.—Hartshorn and Sal Volatile.—Combustion of Ammoniacal Gas.

CONVERSATION XIV.

ON EARTHS.

48

Composition of the Earths.—Of their Incombustibility.—They form the bases of all Minerals.—Their Alkaline Properties.—Silex; its Properties and Uses in the Arts.—Alumine; its Uses in Pottery, &c.—Alkaline Earths.—Barytes.—Lime; its extensive chemical Properties, and Uses in the Arts.—Magnesia.—Strontian.

CONVERSATION XV.

ON ACIDS.

70

Nomenclature of the Acids.—Of the Classification of Acids:—1st Class—Acids of simple and known Radicals, or Mineral Acids. 2d Class—Acids of double Radicals, or Vegetable Acids. 3d Class—Acids of triple Radicals, or Animal Acids.—Of the Decomposition of Acids of the 1st Class by Combustible Bodies.

CONVERSATION XVI.

	Page
OF THE SULPHURIC AND PHOSPHORIC ACIDS; OR, THE COMBINATIONS OF OXYGEN WITH SULPHUR AND PHOSPHORUS; AND OF THE SULPHATES AND PHOS- PHATES.	80

Of the Sulphuric Acid.—Combustion of Animal or Vegetable Bodies by this Acid.—Method of preparing it.—The Sulphurous Acid obtained in the Form of Gas.—May be obtained from Sulphuric Acid.—May be reduced to Sulphur.—Is absorbable by Water.—Destroys Vegetable Colours.—Experiment of freezing Water in a red-hot ladle.—Oxide of Sulphur.—Of Salts in General.—Sulphates.—Sulphate of Potash.—Cold produced by the Melting of Salts.—Sulphate of Soda, or Glauber's Salt.—Heat evolved during the Formation of Salts. Crystallisation of Salts.—Water of Crystallisation.—Efflorescence and Deliquescence of Salts.—Sulphate of Lime, Gypsum, or Plaster of Paris.—Sulphate of Magnesia.—Sulphate of Alumine or Alum.—Sulphate of Iron.—Of Ink.—Of the Phosphoric and Phosphorous Acids.—Phosphorus obtained from Bones.—Phosphate of Lime.

CONVERSATION XVII.

OF THE NITRIC AND CARBONIC ACIDS; OR, THE COM- BINATIONS OF OXYGEN WITH NITROGEN AND CAR- BON; AND OF THE NITRATES AND CARBONATES.	101
--	-----

Nitrogen susceptible of various Degrees of Acidification.
—Of the Nitric acid.—Its Nature and Composition discovered by Mr. Cavendish.—Obtained from Nitrate of Potash.—Aqua Fortis.—Nitric Acid may be con-

	Page
verted into Nitrous Acid.—Nitric Oxide Gas.—Its Conversion into Nitrous Acid Gas.—Used as a Eu- diometrical Test.—Gaseous Oxide of Nitrogen, or exhilarating Gas, obtained from Nitrate of Ammonia. —Its singular Effects on being respired.—Nitrates. —Of Nitrate of Potash, Nitrate, or Saltpetre.—Of Gunpowder.—Causes of Detonation.—Decomposi- tion of Nitre.—Deflagration,—Nitrate of Ammonia. —Nitrate of Silver.—Of the Carbonic Acid.— Formed by the Combustion of Carbon.—Constitutes a component Part of the Atmosphere.—Exhaled in some Caverns.—Grotto del Cane.—Great Weight of this Gas.—Produced from Calcareous Stones by Sulphuric Acid.—Deleterious Effects of this Gas when respired.—Sources which keep up a Supply of this Gas in the Atmosphere.—Its Effects on Vegetation.—Of the Carbonates of Lime; Marble, Chalk, Shells, Spars, and Calcareous Stones.	

CONVERSATION XVIII.

ON THE BORACIC, FLUORIC, AND MURIATIC ACIDS; AND ON MURIATES.—ON CHLORINE AND CHLORATES.— ON IODINE AND IODIC ACID.—ON BROME.	129
---	-----

On the Boracic Acid.—Its Decomposition by Sir H. Davy.—Its Basis Boracium.—Its Recomposition.—Its Uses in the Arts.—Borax or Borate of Soda.—Of the Fluoric Acid.—Obtained from Fluor; corrodes Siliceous Earth; its supposed Composition.—Fluorine; its supposed Basis.—Of the Muriatic Acid.—Obtained from Muriates.—Its gaseous Form.—Is absorbable by Water.—Its Decomposition.—Of Chlorine.—Its gaseous Form and other Properties.—Combustion of Bodies in this Gas.—It dissolves Gold.—Composition of Aqua Regia.—Chlorine

destroys all Colours.—Used for bleaching and for Fumigations.—Its offensive Smell, &c.—Combinations of Chlorine.—Muriates.—Muriate of Soda, or Common Salt.—Muriate of Ammonia.—Chlorates.—Chlorate of Potash.—Detonates with Sulphur, Phosphorus, &c.—Experiment of burning Phosphorus under Water by means of this Salt and of Sulphuric Acid.—Iodine; its Form and Colour; obtained from Sea-weed; its Combinations.—Brome; its Combinations.—Condensation of Gases to a liquid or a solid State; Experiments of Mr. Faraday on the Gases.

CONVERSATION XIX.

ON THE NATURE AND COMPOSITION OF VEGETABLES. 157

Of organised Bodies.—Of the Functions of Vegetables.—Of the Elements of Vegetables.—Of the Materials of Vegetables.—Analysis of Vegetables.—Of Sap.—Mucilage, or Gum.—Sugar.—Manna and Honey.—Gluten.—Vegetable Oils.—Fixed Oils.—Linseed, Nut, and Olive Oils.—Volatile Oils, forming Essences and Perfumes.—Camphor.—Resins and Varnishes.—Pitch, Tar, Copal, Mastic, &c.—Gum Resins.—Myrrh, Assafœtida, &c.—Caoutchouc, or Gum Elastic.—Extractive colouring Matter; its Use in the Arts of Dyeing and Painting.—Tannin; its Use in the Art of preparing Leather.—Woody Fibre.—Vegetable Acids.—The Alkalies and Salts contained in Vegetables.—New Vegetable Alkalies.

CONVERSATION XX.

ON THE DECOMPOSITION OF VEGETABLES. 199

Of Fermentation in general.—Of the Saccharine Fermentation, the Product of which is Sugar.—Of the

	Page
Vinous Fermentation, the Product of which is Wine. — Alcohol, or Spirit of Wine. — Analysis of Wine by Distillation. — Of Brandy, Rum, Arrack, Gin, &c. — Tartrate of Potash, or Cream of Tartar. — Liquors. — Chemical Properties of Alcohol. — Its Combustion. — Of Ether. — Of the Acetous Fermentation, the Product of which is Vinegar. — Fermentation of Bread. — Of the Putrid Fermentation, which reduces Vegetables to their Elements. — Spontaneous Suc- cession of these Fermentations. — Of Vegetables said to be petrified. — Of Bitumens : Naphtha, Asphaltum, Jet, Coal, Succin, or Yellow Amber. — Of Fossil, Wood, Peat, and Turf.	

CONVERSATION XXI.

HISTORY OF VEGETATION.	238
------------------------	-----

Connection between the Animal, Vegetable, and Mineral Kingdoms. — Of Manures. — Of Agriculture. — Of the Sustenance which Plants derive from the Soil. — Of Humus. — Of Natural Vegetation. — Of Vegetation by Cultivation. — Of the Sustenance which Plants derive from the Atmosphere. — Vegetation of Trees, of Starch. — Rotation of Crops. — Inexhaustible Sources of Materials for the Purposes of Agriculture.

CONVERSATION XXII.

VEGETATION CONTINUED.	272
-----------------------	-----

Of Sowing Seed. — Germination of the Seed. — Function of the Leaves of Plants. — Effects of Light and Air on Vegetation. — Effects of Water on Vegeta-

Page

tion.—Effects of Vegetation on the Atmosphere.—
Formation of Vegetable Materials by the Organs of
Plants.—Vegetable Heat.—Of the Organs of Plants.
—Of the Bark, consisting of Epidermis, Parenchyma,
and Cortical Layers.—Of Alburnum, or Wood.—
Leaves, Flowers, and Seeds.—Effects of the Sea-
son on Vegetation.—Vegetation of Evergreens in
Winter.

CONVERSATION XXIII.

ON THE COMPOSITION OF ANIMALS.

295

Elements of Animals.—Of the principal Materials of
Animals, viz. Gelatine, Albumen, Fibrine, Mucus.—
Of Animal Acids.—Of Animal Colours, Prussian
Blue, Carmine and Ivory Black.

CONVERSATION XXIV.

ON THE ANIMAL ECONOMY.

314

Of the principal Animal Organs.—Of Bones, Teeth,
Horns, Ligaments, and Cartilages.—Of the Muscles
constituting the Organs of Motion.—Of the Vascular
System for the Conveyance of Fluids.—Of the
Glands, for the Secretion of Fluids.—Of the Nerves,
constituting the Organs of Sensation.—Of the Cel-
lular Substance which connects the several Organs.
—Of the Skin.

CONVERSATION XXV.

ON ANIMALISATION, NUTRITION, AND RESPIRATION. 330

Digestion.—Solvent Power of the Gastric Juice.—
Formation of Chyle.—Its Assimilation, or Conver-

	Page
sion into Blood.—Of Respiration.—Mechanical Process of Respiration.—Chemical Process of Respiration.—Of the Circulation of the Blood.—Of the Functions of the Arteries, the Veins, and the Heart.—Of the Lungs.—Effects of Respiration on the Blood.	

CONVERSATION XXVI.

ON ANIMAL HEAT, AND ON VARIOUS ANIMAL PRODUCTS. 354

Of the Analogy of Combustion and Respiration.—Animal Heat evolved in the Lungs.—Animal Heat evolved in the Circulation.—Heat is produced by Fever.—Perspiration.—Heat produced by Exercise.—Equal Temperature of Animals at all Seasons.—Power of the Animal Body to resist the effects of Heat.—Cold produced by Perspiration.—Respiration of Fishes and of Birds.—Effects of Respiration on Muscular Strength.—Of several Animal Products, viz. Milk, Butter, and Cheese; Spermaceti; Ambergris; Wax; Lac; Silk; Musk; Civet; Castor.—Silk.—Of the Putrid Fermentation.—Conclusion.

CONVERSATIONS
ON
C H E M I S T R Y.

CONVERSATION XII.

ON THE ATTRACTION OF COMPOSITION.

MRS. B.

HAVING completed our examination of the simple or elementary bodies, we are now to proceed to those of a compound nature: but, before we enter on this extensive subject, it will be necessary to make you acquainted with the principal laws by which chemical combinations are governed.

You recollect, I hope, what we formerly said of the nature of the attraction of composition, or chemical attraction, or affinity as it is also called?

EMILY.

Yes, I think, perfectly: it is the attraction that subsists between bodies of a different nature, which occasions them to combine and form a compound, when they come in contact.

MRS. B.

Very well; your definition comprehends the first

VOL. II. B

law of chemical attraction, which is, that *it takes place only between bodies of a different nature* ; as, for instance, between an acid and an alkali ; between oxygen and a metal, &c.

CAROLINE.

That we understand, of course ; for the attraction between particles of a similar nature is that of aggregation, or cohesion, which is independent of any chemical power.

MRS. B.

The second law of chemical attraction is, that *it takes place only between the most minute particles of bodies* ; therefore, the more you divide the particles of the bodies to be combined, the more readily they act upon each other.

CAROLINE.

This is again a circumstance which we might have inferred ; for the finer the particles of the two substances are, the more easily and perfectly they will come in contact with each other, which must greatly facilitate their union. It was for this purpose, you said, that you used iron filings, in preference to wires or pieces of iron, for the decomposition of water.

MRS. B.

It was once supposed that no mechanical power could divide bodies into particles sufficiently minute for them to act chemically on each other ; and that, in order to produce the extreme division requisite

for that purpose, one, if not both, of the bodies should be in a fluid state. There are, however, a few instances in which two solid bodies, very finely pulverised, exert a chemical action on each other; but such exceptions to the general rule are very rare.

EMILY.

In all the combinations that we have hitherto seen, one of the constituents has, I believe, been either liquid or aëriform. In combustions, for instance, the oxygen is taken from the atmosphere, in which it existed in the state of gas; and whenever we have seen acids combine with metals or with alkalies, they were either in a liquid or an aëriform state.

MRS. B.

The third law of chemical attraction is, that *it can take place between two, three, four, or even a greater number of bodies.*

CAROLINE.

Oxides and acids are bodies composed of two constituents; but I recollect no instance of the combination of a greater number of principles.

MRS. B.

The compound salts, formed by the union of the metals with acids, are composed of three principles. And there are salts, formed by the combination of the alkalies with the earths which are of a similar description.

CAROLINE.

Are they of the same kind as the metallic salts?

MRS. B.

Yes; they are very analogous in their nature, although different in many of their properties.

A methodical nomenclature, similar to that of the acids, has been adopted for the compound salts. Each individual salt derives its name from its constituent parts, so that every name implies a knowledge of the composition of the salt.

The three alkalies, the alkaline earths, and the metals are called *salifiable bases* or *radicals*; and the acids *salifying principles*. The name of each salt is composed both of that of the acid and the salifiable base; and it terminates in *ate* or *ite*, according to the degree of the oxygenation of the acid. Thus, for instance, all those salts which are formed by the combination of the sulphuric acid with any of the salifiable bases are called *sulphates*, and the name of the radical is added for the specific distinction of the salt: if it be potash, it will compose a *sulphate of potash*: if ammonia, *sulphate of ammonia*, &c.

EMILY.

The crystals which we obtained from the combination of iron and sulphuric acid were therefore *sulphate of iron*?

MRS. B.

Precisely: and those which we prepared by dis-

solving copper in nitric acid, *nitrate of copper*, and so on. But this is not all: if the salt be formed by that class of acids which ends in *ous* (which you know indicates a less degree of oxygenation), the termination of the name of the salt will be in *ite*, as *sulphite of potash*, *sulphite of ammonia*, &c.

EMILY.

There must be an immense number of compound salts, since there is so great a variety of salifiable radicals, as well as of salifying principles.

MRS. B.

Their real number cannot be ascertained, since it increases every day. But we must not proceed further in the investigation of the compound salts, until we have completed the examination of the nature of the ingredients of which they are composed.

The fourth law of chemical attraction is, that *a change of temperature always takes place at the moment of combination*. This arises from the extrication of caloric, which invariably occurs when bodies unite; and also sometimes in part from a change of capacity of the bodies for heat, which always takes place when the combination is attended with an increase of density, but more especially when the compound passes from the liquid to the solid form. I shall now show you a striking instance of a change of temperature from chemical union, merely by pouring some nitric acid on this small

quantity of oil of turpentine — the oil will instantly combine with the oxygen of the acid, and produce a considerable change of temperature.

CAROLINE.

What a blaze! the temperature of the oil and the acid must be greatly raised, indeed, to produce such a violent combustion.

MRS. B.

There is, however, a peculiarity in this combustion, which is, that the oxygen, instead of being derived from the atmosphere alone, is principally supplied by the acid itself.

EMILY.

And are not all combustions instances of the change of temperature produced by the chemical combination of two bodies?

MRS. B.

Undoubtedly: when oxygen loses its gaseous form, in order to combine with a solid body, it becomes condensed, and the caloric evolved produces the elevation of temperature. The specific gravity of bodies is at the same time altered by chemical combination; for, in consequence of a change of capacity for heat, a change of density must be produced.

CAROLINE.

That was the case with the sulphuric acid and water, which, by being mixed together, gave out a great deal of heat, and increased in density.

MRS. B.

The fifth law of chemical attraction is, that the *properties which characterise bodies when separate are altered or destroyed by their combination.*

CAROLINE.

Certainly: what, for instance, can be so different from water as the hydrogen and oxygen gases?

EMILY.

Or what more unlike sulphate of iron than iron or sulphuric acid?

MRS. B.

Every chemical combination is an illustration of this rule. But let us proceed:—

The sixth law is, that *the force of chemical affinity between the constituents of a body is estimated by that which is required for their separation.* This force is not always proportional to the facility with which bodies unite; for manganese, for instance, which, you know, is so much disposed to unite with oxygen, that it is never found in a metallic state, yields it more easily than any other metal.

EMILY.

But, Mrs. B., you speak of estimating the force of attraction between bodies by the force required to separate them: how can you measure these forces?

MRS. B.

They cannot be precisely *measured*, but they

are comparatively ascertained by experiment, and can be represented by numbers which express, at least by approximation, the relative degrees of attraction.

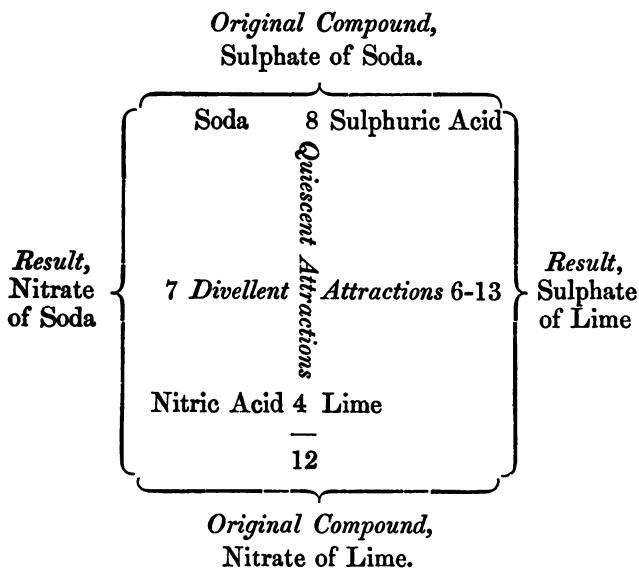
The seventh law is, that *bodies have amongst themselves different degrees of attraction*. Upon this law the whole science of chemistry depends; for it is by means of the various degrees of affinity which bodies have for each other, that all the chemical compositions and decompositions are effected. Whenever the decomposition of a body is performed by the addition of any single new substance, it is said to be effected by *simple elective attractions*. But it often happens that no simple substance will decompose a body, and that, in order to effect this, you must offer to the compound a body which is itself composed of two, or sometimes three, principles, which would not, each separately, perform the decomposition. In this case, there are two new compounds formed in consequence of a reciprocal decomposition and recombination. All instances of this kind are called *double elective attractions*.

CAROLINE.

I confess I do not understand this clearly.

MRS. B.

You will easily comprehend it by the assistance of this diagram, in which the reciprocal forces of attraction are represented by numbers : —



We here suppose that we are to decompose sulphate of soda; that is, to separate the acid from the alkali: if, for this purpose, we add some lime, in order to make it combine with the acid, we shall fail in our attempt, because the soda and the sulphuric acid attract each other by a force which is superior, and (by way of supposition) is represented by the number 8; while the lime tends to unite with this acid by an affinity equal only to the number of 6. It is plain, therefore, that the sulphate of soda will not be decomposed, since a force equal to 8 cannot be overcome by a force equal only to 6.

CAROLINE.

So far, this appears very clear.

MRS. B.

If, on the other hand, we endeavour to decompose this salt by nitric acid, which tends to combine with soda, we shall be equally unsuccessful, as nitric acid tends to unite with the alkali by a force equal only to 7.

In neither of these cases of simple elective attraction, therefore, can we accomplish our purpose. But let us previously combine together the lime and nitric acid, so as to form a nitrate of lime, a compound salt, the constituents of which are united by a power equal to 4. If, then, we present this compound to the sulphate of soda, a decomposition will ensue, because the sum of the forces which tend to preserve the two salts in their actual state is not equal to that of the forces which tend to decompose them, and to form new combinations. The nitric acid, therefore, will combine with the soda, and the sulphuric acid with the lime.

CAROLINE.

I understand you now very well. This double effect takes place because the numbers 8 and 4, which represent the degrees of attraction of the constituents of the two original salts, make a sum less than the number 7 and 6, which represent the degrees of attraction of the two new compounds that will in consequence be formed.

MRS. B.

Precisely so.

CAROLINE.

But what is the meaning of *quiescent* and *divellent* forces, which are written in the diagram?

MRS. B.

Quiescent forces are those which tend to preserve compounds in a state of rest, or such as they actually are : divellent forces, those which tend to destroy that state of combination, and to form new compounds.

These are the principal circumstances relative to the doctrine of chemical attractions which have been laid down as rules by modern chemists : a few others might be mentioned respecting the same theory, but of less importance, and such as would take us too far from our plan. I should, however, not omit to mention that Mr. Berthollet, a celebrated French chemist, has questioned the uniform operation of elective attraction, and has advanced the opinion that, in chemical combinations, the changes which take place, and the proportions in which bodies combine, depend not only upon the affinities, but also, in some degree, on the respective quantities of the substances concerned, on the heat applied during the process, and some other circumstances.

CAROLINE.

In that case, I suppose, there would hardly be two compounds exactly similar, though composed of the same materials.

MRS. B.

On the contrary, it is found that a remarkable uniformity prevails, as to proportions, between the ingredients of bodies of similar compositions. Thus water, as you may recollect to have seen in a former conversation, is composed of two volumes of hydrogen gas to one of oxygen; and this is always found to be precisely the proportion of its constituents, from whatever source the water be derived. The same uniformity prevails with regard to the various salts; the acid and alkali, in each kind of salt, being always found to combine in the same proportions. Sometimes, it is true, the same acid and the same alkali are capable of making two distinct kinds of salts; but in all these cases it is found, that one of the salts contains just twice, or, in some instances, thrice as much acid or alkali as the other.

EMILY.

If the proportion in which bodies combine are so constant and so well defined, how can Mr. Berthollet's remark be reconciled with this uniform system of combination?

MRS. B.

Eminent as that philosopher's authority was in chemistry, it is now generally supposed that his doubts on this subject were, in a great degree, groundless; and that the exceptions he has observed in the laws of definite proportions have been only apparent, and may be accounted for consistently with those laws.

EMILY.

I think I understand the law of definite proportions very well, so far as it regards the gases, such as oxygen and hydrogen, in the instance you have just mentioned; but in the case of acids and alkalies, when the bodies are either liquid or solid, I do not conceive how their bulks or volumes can be measured in order to ascertain the proportion in which they combine?

MRS. B.

Your question is quite in point: the fact is, that the law of combination, *by volume*, does not prevail in regard to liquids and solids. In these, we must leave the circumstance of bulk entirely out of consideration. It is to their *weight* that we must attend, in determining the proportions in which they combine; and, accordingly, if we take the combining substances in a state of perfect purity, and ascertain with great accuracy, once for all, the proportions, *by weight*, in which they unite, we shall find that, in every other instance in which

these substances have an opportunity of combining, they will unite in the same proportions, and in no other — unless it be in such proportions that one of the bodies shall be, in weight, exactly double, triple, or quadruple what it was in the former combination.

CAROLINE.

This requires a good deal of attention to be well understood; and I should like to have it illustrated by some particular examples of these different combinations.

MRS. B.

Nothing easier than to satisfy you in this respect. For instance, with regard to bulk, nitrogen gas is capable of combining with oxygen gas, in different proportions: thus, one volume of nitrogen, by combining with one volume of oxygen, forms the substance called nitrous gas; with two volumes of oxygen, it forms nitrous acid gas, &c. And with regard to solids and liquids, the proportions of which are estimated by weight, I may mention, as an example, the case of the salt called sulphate of potash, in which a given weight of potash may combine with two different proportions of sulphuric acid; but the quantity of acid in one case is exactly double what it is in the other.

EMILY.

And pray what can be the cause of this singular uniformity in the law of combination?

MRS. B.

Philosophers have not yet been able to give us any decisive information upon this point; but they explain it in the following manner: since chemical combination takes place between the most minute particles of bodies, may we not suppose that the smallest particles or portions in which bodies combine (and which we may call *chemical atoms*) are capable of uniting together one to one, or sometimes one to two, or one to three, &c., but that they cannot combine in any intermediate proportion?

EMILY.

But, if an atom was broken into two, an intermediate combination would be obtained?

MRS. B.

The nature of the atom is incompatible with the idea of any further division; since the chemical atom is the smallest quantity which chemistry can obtain, and such as no mechanical means can possibly subdivide.

CAROLINE.

And pray what is the use of this doctrine of definite proportions?

MRS. B.

It is very considerable; for it enables chemists to form tables, by which they can see at one glance the composition of all the bodies which have been accurately analysed, and ascertain in an instant

what quantity of one body will be necessary to decompose a certain quantity of another; and, in general, such tables serve to present, in one view, the result of any chemical decomposition, and the quantities of the new compounds formed; by which means a considerable saving of labour is gained, either in enabling us to calculate beforehand the results of any manufacturing operations, or in estimating those obtained in analytical processes. One of the consequences of the atomic theory was supposed to be, that any variation in the number of atoms would produce a body of another description, varying for instance in shape, colour, or other properties from the original body.

EMILY.

Then all bodies that differ in these properties must be of a different composition?

MRS. B.

That would be a natural inference; but since the introduction of the atomic theory it has been discovered, that in many instances bodies alter their appearance, and some of their properties, without any alteration taking place in their constituent parts.

CAROLINE.

What! Mrs. B., do you mean to say that two bodies composed exactly alike may differ in their properties?

MRS. B.

Yes! and even that the same body may undergo these variations. Of this I will show you an example.

CAROLINE.

Oh! I shall be delighted to see your chemical Proteus.

MRS. B.

Look at the powder contained in this bottle: it is iodide of mercury; that is, a combination of iodine and mercury.

EMILY.

What a brilliant red,—it is brighter than vermillion!

MRS. B.

We will put some of it into this plate, and hold it over the lamp.

CAROLINE.

It has changed to a bright yellow colour, like the feathers of a canary bird; but I conclude that the iodine has evaporated, and that this is an oxide of mercury which remains on the plate.

MRS. B.

No, indeed; no chemical change of composition has taken place in the body, as I will prove to you by touching it with this glass tube, which will restore it to its original state.

CAROLINE.

So it does, indeed! it becomes red again as it

was at first: and was your magic wand really nothing more than a glass tube?

MRS. B.

Nothing more, I assure you. This affords a striking example of the same body assuming two different appearances, and a chemical analysis would afford a proof of it.

EMILY.

But do not these apparent differences lead to errors in chemistry? I should think it would create great confusion in regard to the composition of bodies?

MRS. B.

Not so much as you would imagine. These protean bodies are not numerous, and it is always easy to ascertain their character. This phenomenon has been called by chemists *Deamorphism* or *Isomerism*, the first meaning a body showing its different forms, the latter (which is most used) similarity of composition.

EMILY.

Are there any simple bodies which undergo such changes?

MRS. B.

Yes. Sulphur is one of this description. There is some sulphur in this glass tube. I heat it over the lamp, taking care that the temperature should not rise above 234° Fah.

EMILY.

The sulphur melts, and looks like clear water.

MRS. B.

Now, by, increasing the temperature you see that it becomes of a deep yellow, but is still very liquid.

CAROLINE.

Yes; these are two transformations it has already undergone.

MRS. B.

Now I drop some of it out of the tube, and you see that it immediately becomes solid and yellow, like common sulphur. I continue heating it, and the temperature has now risen from 482° to 500° .

CAROLINE.

But, Mrs. B., have you not burnt the sulphur, for it is become quite black?

MRS. B.

No; if the sulphur were burnt there would be a change in the composition of the body, for the sulphur would have combined with oxygen. It is therefore only another metamorphosis it undergoes. The sulphur, you may now observe, is very thick and viscous, so much so that it will not run out of the tube when I hold the open end downwards. The sulphur is now in a soft but solid state, which may be moulded into any shape you

please. I will take off the impression of a new shilling with it.

EMILY.

The impression is very exact, but I fear we cannot preserve it, the sulphur is so soft.

MRS. B.

In a few moments it will undergo its final transformation by returning to its original state, and become hard and yellow. Sulphur in this soft state has been used for making correct moulds of small objects. Phosphorus presents analogous phenomena. When melted in a tube it is almost as transparent as water, then if suddenly cooled it becomes opaque and black, but resumes its transparency when again melted and cooled gradually.

EMILY.

And pray, Mrs. B., how are these phenomena explained?

MRS. B.

The only explanation that can be given of these various changes is, that the properties of bodies depend not only on the proportion of atoms of their constituents, but also on the peculiar arrangement of these atoms respecting each other. But I perceive the subject is becoming rather too intricate for us. We must not run the risk of entering into difficulties which might confuse your ideas, and throw more obscurity than interest

upon this abstruse part of the philosophy of chemistry.

CAROLINE.

Pray, Mrs. B., can you decompose a salt by means of electricity, in the same way as we decompose water?

MRS. B.

Undoubtedly; and I am glad this question occurred to you, because it gives me an opportunity of showing you some very interesting experiments on the subject.

If we dissolve a quantity, however small, of any salt in a glass of water, and plunge into it the extremities of the wires which proceed from the two ends of the Voltaic battery, the salt will be gradually decomposed, the acid being attracted by the positive, and the alkali by the negative, wire.

EMILY.

But how can you render that decomposition perceptible?

MRS. B.

By placing in contact with the extremities of each wire, in the solution, pieces of paper stained with certain vegetable colours, which are altered by the contact of an acid or an alkali. Thus, this blue vegetable preparation called litmus becomes red when touched by an acid; and the juice of violets becomes green by the contact of an alkali.

But the experiment can be made in a much more distinct manner, by receiving the extremities of the wires into different vessels, so that the alkali shall appear in one vessel and the acid in the other.

CAROLINE.

But then the Voltaic circle will not be completed: how therefore can any effect be produced?

MRS. B.

You are right. I ought to have added, that the two vessels must be connected together by some interposed substance capable of conducting electricity. A piece of moistened cotton-wick answers this purpose very well. You see that the cotton (Plate XVI. fig. 2. c.) has one end immersed in one glass and the other end in the other, so as to establish a communication between any fluids contained in them. We shall put into each of the glasses a little Glauber's salt, or sulphate of soda (which consists of an acid and alkali), and then fill the glasses with water, which will dissolve the salt. Let us now connect the glasses by means of the wires (*e, d,*) with the two ends of the battery thus —

CAROLINE.

The wires are already giving out small bubbles: is this owing to the decomposition of the salt?

MRS. B.

No: these are bubbles produced by the decom-

Fig. 1.
Voltaic Battery.

PLATE XVI

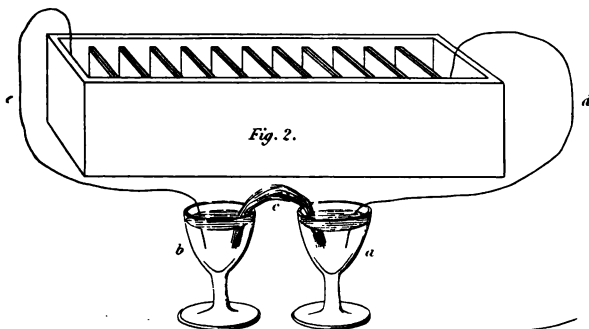
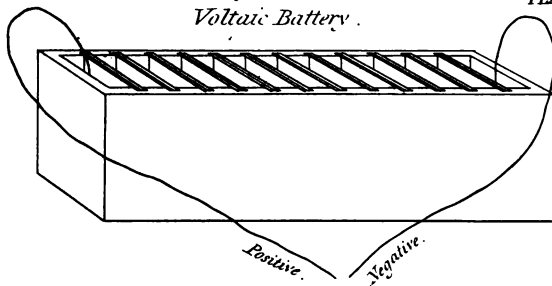


Fig. 3.



Fig. 4.

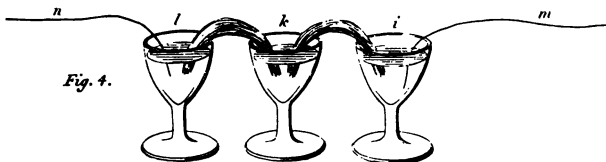


Fig. 1. Voltaic Battery.

Fig. 2, 3 & 4. Instances of Chemical decomposition by the Voltaic Battery.

1

1

position of the water, as you saw in the former experiment. In order to render the separation of the acid from the alkali visible, I pour into the glass (*a*), which is connected with the positive wire, a few drops of a solution of litmus, which the least quantity of acid turns red; and into the other glass (*b*), which is connected with the negative wire, I pour a few drops of the juice of violets —

EMILY.

The blue solution is already turning red all round the wire.

CAROLINE.

And the violet solution is beginning to turn green. This is, indeed, very singular!

MRS. B.

You will be still more astonished when we vary the experiment in this manner: — These three glasses (fig. 3. *f*, *g*, *h*,) are, as in the former instance, connected together by wetted cotton, but the middle one alone contains a saline solution, the two others nothing but distilled water, coloured, as before, by vegetable infusions. Yet, on making the connection with the battery, the alkali will appear in the negative glass (*h*), and the acid in the positive glass (*f*), though there was no saline matter in either of them.

EMILY.

So that the acid and alkali must be conveyed

24 ON THE ATTRACTION OF COMPOSITION.

right and left from the central glass into the others, by means of the connecting moistened cotton?

MRS. B.

Exactly so ; and you may render the experiment still more striking by putting into the central glass (*k*, fig. 4.) an alkaline solution, the Glauber's salt being placed in the negative glass (*l*), and the positive glass (*i*) containing only water. The acid will be attracted by the positive wire (*m*), and will actually appear in the vessel (*i*), after passing through the alkaline solution (*k*), without combining with it, although, you know, acids and alkalies are so much disposed to combine. But our conversation has already much exceeded its usual limits, so we cannot enlarge more upon this interesting subject at present.

CONVERSATION XIII.

ON ALKALIES.

MRS. B.

HAVING now given you some idea of the laws by which chemical attractions are governed, we may proceed to the examination of bodies which are formed in consequence of these attractions.

The first class of compounds which present themselves to our notice, in our gradual ascent to the most complicated combinations, are bodies composed of only two principles. The sulphurets, phosphurets, carburets, &c., are of this description ; but the most numerous and important of these compounds are the combinations of oxygen with the various simple substances with which it has a tendency to unite. Of these you have already acquired some knowledge ; but it will be necessary to enter into further particulars respecting the nature and properties of those most deserving of our notice. Of this class are the ALKALIES and the EARTHS, which we shall successively examine.

We shall first take a view of the alkalies, of which there are three, viz. POTASH, SODA, and AMMONIA ;

the two former being, as you may recollect, a combination of the metallic substances potassium and sodium with oxygen. They are called *fixed alkalies**, because they exist in a solid form at the temperature of the atmosphere, and require a great heat to be volatilised; and consist, as you already know, of metallic bases combined with oxygen. In potash, the proportions are about eighty-six parts of potassium to fourteen of oxygen; and, in soda, seventy-seven parts of sodium to twenty-three of oxygen. The third alkali, ammonia, has been distinguished by the name of *volatile alkali*, because its natural form is that of gas. Its composition is of a more complicated nature, of which we shall speak hereafter.

Some of the earths bear so strong a resemblance in their properties to the alkalies, that it is difficult to know under which head to class them. The celebrated French chemist, Fourcroy, has placed two of them (barytes and strontites) with the alkalies; but, as lime and magnesia have almost an equal title to that rank, I think it better not to

* It has already been stated that a third fixed alkali has been discovered by Mr. Arfwedson, which has been called *lithion*. It was first found in a Swedish mineral called *petalite*; but has since been detected in some other minerals. Though this alkali resembles potash and soda in its general properties, yet it is decidedly an alkaline substance of its own, capable of forming different salts with the acids, and having in particular the property of combining with much greater proportions of acid than the other alkalies.

separate them, and, therefore, have adopted the common method of classing them with the earths, and of distinguishing them by the name of *alkaline earths*.

The general properties of alkalies are, an acrid burning taste, a pungent smell, and a caustic action on the skin and flesh.

CAROLINE.

I wonder they should be caustic, Mrs. B., since they contain so little oxygen.

MRS. B.

Whatever substance has an affinity for any one of the constituents of animal matter, sufficiently powerful to decompose it, is entitled to the appellation of caustic. The alkalies, in their pure state, have a very strong attraction for water, for hydrogen, and for carbon, which, you know, are the constituent principles of oil; and it is chiefly by absorbing these substances from animal matter that they effect its decomposition; for, when diluted with a sufficient quantity of water, or combined with any oily substance, they lose their causticity.

But, to return to the general properties of alkalies—they change, as we have already seen, the colour of syrup of violets, and other blue vegetable infusions, to green; and have, in general, a very great tendency to unite with acids, although the respective qualities of these two classes of bodies form a remarkable contrast.

We shall examine the result of the combination of acids and alkalies more particularly hereafter. It will be sufficient at present to inform you, that whenever acids are brought in contact with alkalies or alkaline earths, they unite with a remarkable eagerness, and form compounds perfectly different from either of their constituents: these bodies are called *neutral* or *compound salts*.

The dry white powder which you see in this phial is pure caustic POTASH: it is very difficult to preserve it in this state, as it attracts, with extreme avidity, the moisture from the atmosphere; and, if the air were not perfectly excluded, it would, in a very short time, be actually melted.

EMILY.

It is then, I suppose, always found in a liquid state?

MRS. B.

No; it exists in nature in a great variety of forms and combinations, but it is never found in its pure separate state: it is combined with carbonic acid, with which it exists in every part of the vegetable kingdom, and is most commonly obtained from the ashes of vegetables, which are the residue that remains after all the other parts have been volatilised by combustion.

CAROLINE.

But you once said that, after all the volatile parts of a vegetable were evaporated, the substance that remained was charcoal?

MRS. B.

I am surprised that you should still confound the processes of volatilisation and combustion. In order to procure charcoal, we evaporate such parts as can be reduced to vapour by the operation of heat alone; but, when we *burn* the vegetable, we burn the carbon also, and convert it into carbonic acid gas.

CAROLINE.

That is true: I hope I shall make no more mistakes in my favourite theory of combustion.

MRS. B.

Potash derives its name from the *pots* in which the vegetables, from which it was obtained, used formerly to be burnt: the alkali remained mixed with the ashes at the bottom, and was thence called potash.

EMILY.

The ashes of a wood-fire, then, must be potash, since they are vegetable ashes.

MRS. B.

They always contain more or less potash, but are very far from consisting of that substance alone, as they are a mixture of various earths and salts which remain after the combustion of the vegetables, and from which it is not easy to separate the alkali in its pure form. The process by which potash is obtained, even in the imperfect state in which it is used in the arts, is much more complicated than

simple combustion. It was once deemed impossible to separate it entirely from all foreign substances, and it is only in chemical laboratories that it is to be met with in the state of purity in which you find it in this phial. Wood-ashes are, however, valuable for the alkali which they contain, and are used for some purposes without any further preparation. Purified in a certain degree, they make what is commonly called *pearlash*, which is of great efficacy in extracting grease, in washing linen, &c.: for potash combines readily with oil or fat, with which it forms a compound well known to you under the name of *soap*.

CAROLINE.

Really! Then I should think it would be better to wash all linen with pearlash than with soap, as, in the latter case, the alkali, being already combined with oil, must be less efficacious in extracting grease.

MRS. B.

Its effect would be too powerful on fine linen, and would injure its texture; pearlash is, therefore, only used for that which is of a strong coarse kind. For the same reason, you cannot wash your hands with plain potash; but, when mixed with oil in the form of soap, it is soft as well as cleansing, and is, therefore, much better adapted to the purpose.

Caustic potash, as we already observed, acts on the skin and animal fibre in virtue of its attraction

for water and oil, and converts all animal matter into a kind of saponaceous jelly.

EMILY.

Are vegetables the only source from which potash can be derived ?

MRS. B.

No; for, though far most abundant in vegetables, it is by no means confined to that class of bodies, being found also on the surface of the earth, mixed with various minerals, especially with earths and stones, whence it is supposed to be conveyed into vegetables by the roots of the plant. It is also met with, though in very small quantities, in some animal substances. The most common state of potash is that of *carbonate*; I suppose you understand what that is?

EMILY.

I believe so: though I do not recollect that you ever mentioned the word before; but I conclude that it must be a compound salt, formed by the union of carbonic acid with potash.

MRS. B.

Very true; you see how admirably the nomenclature of modern chemistry is adapted to assist the memory: when you hear the name of a compound you necessarily learn what are its constituent parts; and when you are acquainted with these constituents, you can immediately name the compound which they form.

CAROLINE.

Pray, how were bodies arranged and distinguished before this nomenclature was introduced?

MRS. B.

Chemistry was then a much more difficult study; for every substance had an arbitrary name, which it derived either from the person who discovered it, as *Glauber's salts*, or from some other circumstance relative to it, though quite unconnected with its real nature, as *potash*.

These names have been retained for some of the simple bodies; for, as this class is not numerous, and, therefore, can be easily remembered, it has not been thought necessary to change them.

EMILY.

Yet I think it would have rendered the new nomenclature more complete to have methodised the names of the elementary as well as of the compound bodies, though it could not have been done in the same manner. But the names of the simple substances might have indicated their nature, or, at least, some of their principal properties; and if, like the acids and compound salts, all the simple bodies had a similar termination, they would have been immediately known as such. So complete and regular a nomenclature would, I think, have given a clearer and more comprehensive view of chemistry than the present, which is a medley of the old and new terms.

MRS. B.

But you are not aware of the difficulty of introducing into science an entire set of new terms: it obliges all the teachers and professors to go to school again; and, if some of the old names which are least exceptionable were not left as an introduction to the new ones, few people would have had industry and perseverance enough to submit to the study of a completely new language; and the inferior classes of artists, who act only from habit and routine, would, at least for a time, have felt material inconvenience from a total change of their habitual terms. From these considerations, Lavoisier and his colleagues, who invented the new nomenclature, thought it most prudent to leave a few links of the old chain, in order to connect it with the new one. Besides, you may easily conceive the inconvenience which might arise from giving a regular nomenclature to substances the simple nature of which is always uncertain; for the new names might, perhaps, in time have proved to have been founded in error. And, indeed, cautious as the inventors of the modern chemical language have been, it has already been found necessary to modify it in many respects. In those few cases, however, in which new terms have been adopted to designate simple bodies, these names have been so contrived as to indicate one of the chief properties of the body in question: this is the case with oxygen, which, as I explained to you, signifies generator of

acids ; and hydrogen, generator of water.* If all the elementary bodies had a similar termination, as you propose, it would be necessary to change the name of any that might hereafter be found to be of a compound nature, which would be very inconvenient in this age of discovery.

But to return to the alkalies : — We shall now try to melt some of this caustic potash in a little water, as a circumstance occurs during its solution very worthy of observation. Do you feel the heat that is produced ?

CAROLINE.

Yes, I do ; but is not this directly contrary to our theory of latent heat, according to which caloric is disengaged when fluids become solid, and cold produced when solids are melted ?

MRS. B.

The latter is really the case in all solutions ; and, if the solution of caustic alkalies seems to make an exception to the rule, it does not form any solid objection to the theory. The matter may be explained thus : When water first comes in contact with the potash, it produces an effect similar to the slacking of lime, that is, the water is

* It may here be observed that, even with regard to these two bodies, the nomenclature is become exceptionable, since it is now found that oxygen is one of the constituents of alkalies as well as of acids, and that hydrogen enters into the composition of some of the acids, and in particular into that of muriatic acid.

solidified in combining with the potash, and thus loses its latent heat: this is the heat that you now feel, and which is, therefore, produced, not by the melting of the solid, but by the solidification of the fluid. But, when there is more water than the potash can absorb and solidify, the latter then yields to the solvent power of the water; and, if we do not perceive the cold produced by its melting, it is because it is counterbalanced by the heat previously disengaged.*

A very remarkable property of potash is the formation of glass by its fusion with siliceous earth. You are not yet acquainted with this last substance, farther than its being in the list of simple bodies. It is sufficient for the present, that you should know that sand and flint are chiefly composed of it: alone it is infusible, but, mixed with potash, it melts when exposed to the heat of a furnace, combines with the alkali, and runs into glass.

CAROLINE.

Who would ever have supposed, that the same substance which converts transparent oil into such an opaque body as soap should transform that opaque substance, sand, into transparent glass!

* This defence of the general theory, however plausible, is liable to some obvious objections. The phenomenon might, perhaps, be better accounted for by supposing that a solution of alkali in water has less capacity for heat than either water or alkali in their separate state.

MRS. B.

The transparency or opacity of bodies does not depend so much upon their intimate nature as upon the arrangement of their particles. We cannot have a more striking instance of this than is afforded by the different states of carbon, which, though it commonly appears in the form of a black opaque body, sometimes assumes the most dazzlingly transparent form in nature, that of a diamond, which, you recollect, is carbon, and which, in all probability, derives its beautiful transparency from the peculiar arrangement of its particles during their crystallisation.

EMILY.

I never should have supposed that the formation of glass was so simple a process as you describe it.

MRS. B.

It is by no means an easy operation to make perfect glass; for if the sand or flint, from which the siliceous earth is obtained, be mixed with any metallic particles, or other substance which cannot be vitrified, the glass will be discoloured, or defaced by opaque specks.

CAROLINE.

That, I suppose, is the reason why objects so often appear irregular and distorted through a common glass window.

MRS. B.

No; this species of imperfection proceeds, gene-

rally, from another cause. It is extremely difficult to prevent the lower part of the vessels, in which the materials of glass are fused, from containing a more dense vitreous matter than the upper, on account of the heavier ingredients falling to the bottom. When this happens, it occasions the appearance of veins or waves in the glass, from the difference of density in its several parts producing an irregular refraction of the rays of light which pass through it.

Another species of imperfection sometimes arises from the fusion not being continued for a length of time sufficient to combine the two ingredients completely, or from the due proportion of potash and silice (which are as two to one) not being carefully observed; the glass, in those cases, will be liable to alteration from the action of the air, of salts, and especially of acids, which will affect its decomposition by combining with the potash, and forming compound salts.

EMILY.

What an extremely useful substance potash is!

MRS. B.

Besides the great importance of potash in the manufactures of glass and soap, it is of very considerable utility in many of the other arts, and in its combinations with several acids, particularly the nitric, with which it forms saltpetre.

CAROLINE.

Then saltpetre must be a *nitrate of potash*? But we are not yet acquainted with the nitric acid.

MRS. B.

We shall therefore defer entering into the particulars of these combinations till we come to a general review of the compound salts. In order to avoid confusion, it will be better at present to confine ourselves to the alkalies.

EMILY.

Cannot you show us the change of colour which you said the alkalies produced on blue vegetable infusions?

MRS. B.

Very easily. I shall dip a piece of white paper into this syrup of violets, which, you see, is of a deep blue, and dyes the paper of the same colour. — As soon as it is dry, I shall then dip it into a solution of potash, which, though itself colourless, will turn the paper green.

CAROLINE.

So it has, indeed! And do the other alkalies produce a similar effect?

MRS. B.

Exactly the same. — We may now proceed to SODA, which, however important, will detain us but a very short time; as in all its general properties it very strongly resembles potash; indeed, so great is their similitude, that they have been

long confounded, and they can now scarcely be distinguished, except by the difference of the salts which they form with acids.

The great source of this alkali is the sea, where, combined with a peculiar acid, it forms the salt with which the waters of the ocean are so strongly impregnated.

EMILY.

Is not that the common table salt?

MRS. B.

The very same; but again we must postpone entering into the particulars of this interesting combination till we treat of the neutral salts. Soda may be obtained from common salt; but the earliest and most usual method of procuring it is by the combustion of marine plants,—an operation perfectly analogous to that by which potash is obtained from land vegetables.

EMILY.

From what does soda derive its name?

MRS. B.

From a plant called by us *soda*, and by the Arabs *kali*, which affords it in great abundance. Kali has, indeed, given its name to the alkalies in general.

CAROLINE.

Does soda form glass and soap in the same manner as potash?

MRS. B.

Yes; and it is of equal importance in the arts,

and is even preferred to potash for some purposes; but you will not be able to distinguish their properties, till we examine the compound salts which they form with acids: we must therefore leave soda for the present, and proceed to AMMONIA, or the VOLATILE ALKALI.

EMILY.

I long to hear something of this alkali: is it not of the same nature as hartshorn?

MRS. B.

Yes, it is, as you will see by-and-by. This alkali is seldom found in nature in its pure state; it is most commonly extracted from a compound salt, called *sal-ammoniac*, which was formerly imported from *Ammonia*, a region of Libya, from which both these salts and the alkali derive their names. The crystals contained in this bottle are specimens of this salt, which consists of a combination of ammonia and muriatic acid.

CAROLINE.

Then it should be called *muriate of ammonia*; for though I am ignorant of what muriatic acid is, yet I know that its combination with ammonia cannot but be so called; and I am surprised to see *sal-ammoniac* inscribed on the label.

MRS. B.

That is the name by which it has been so long known, that the modern chemists have not yet succeeded in banishing it altogether; and it is

still sold under that name by druggists, though by scientific chemists it is more properly called muriate of ammonia.

CAROLINE.

Both the popular and the common name should, I think, be inscribed on labels — this would soon introduce the new nomenclature. By what means can the ammonia be separated from the muriatic acid?

MRS. B.

By chemical attraction; but this operation is too complicated for you to understand till you are better acquainted with the agency of affinities.

EMILY.

And, when extracted from the salt, what kind of substance is ammonia?

MRS. B.

Its natural form, at the temperature of the atmosphere, when free from combination, is that of gas; and in this state it is called *ammoniacal gas*. But it mixes very readily with water, and can be thus obtained in a liquid form. Ammonia consists of about one part of hydrogen to four parts of nitrogen. This was discovered by Berthollet. Having heated ammoniacal gas under a receiver, by causing the electrical spark to pass repeatedly through it, he found that it increased considerably in bulk, lost all its alkaline properties, and was actually converted into hydrogen and nitrogen

gases; and from the latest and most accurate experiments, the proportions appear to be, one volume of nitrogen gas to three of hydrogen gas.

CAROLINE.

Ammonia, therefore, has not, like the two other alkalies, a metallic basis?

MRS. B.

It is believed that it has, though it is extremely difficult to reconcile that idea with what I have just stated of its chemical nature. But the fact is, that although this supposed metallic basis of ammonia has never been obtained distinct and separate, yet both Professor Berzelius, of Stockholm, and Sir H. Davy, have succeeded in forming a combination of mercury with the basis of ammonia, which has so much the appearance of an amalgam that it strongly corroborates the idea of ammonia having a metallic basis.* But these theoretical points are full of difficulties and doubts.

Let us therefore return to the properties of volatile alkali. Ammoniacal gas is considerably lighter than oxygen gas, and only about half the

* This amalgam is easily obtained, by placing a globule of mercury upon a piece of muriate or carbonate of ammonia, and electrifying this globule by the Voltaic battery. The globule instantly begins to expand to three or four times its former size, and becomes much less fluid, though without losing its metallic lustre,—a change which is ascribed to the metallic basis of ammonia uniting with the mercury. This is an extremely curious experiment.

weight of atmospherical air. It possesses most of the properties of the fixed alkalies; but cannot be of so much use in the arts, on account of its volatile nature. It is, therefore, never employed in the manufacture of glass, but it forms soap with oils equally as well as potash and soda; it resembles them likewise in its strong attraction for water; for which reason it can be collected in a receiver over mercury only.

CAROLINE.

I do not understand this.

MRS. B.

You recollect the method which we used to collect gases in a glass receiver over water: well, ammoniacal gas has so strong a tendency to unite with water, that, instead of passing through that fluid, it would be instantaneously absorbed by it. We can therefore neither use water for that purpose, nor any other liquid of which water is a component part; so that, in order to collect this gas, we are obliged to have recourse to mercury (a liquid which has no action upon it), and a mercurial bath is used instead of a water bath, such as we employed on former occasions. Water impregnated with this gas is nothing more than the fluid which you mentioned at the beginning of the conversation — hartshorn; it is the ammoniacal gas escaping from the water which gives it so powerful a smell.

EMILY.

But there is no appearance of effervescence in hartshorn.

MRS. B.

Because the particles of gas which rise from the water are too subtle and minute for their effect to be visible.

Water diminishes in density by being impregnated with ammoniacal gas; and this augmentation of bulk increases its capacity for caloric.

EMILY.

In making hartshorn, then, or impregnating water with ammonia, heat must be absorbed, and cold produced?

MRS. B.

That effect would take place if it were not counteracted by another circumstance: the gas is liquefied by incorporating with the water, and gives out its latent heat. The condensation of the gas more than counterbalances the expansion of the water; therefore, upon the whole, heat is produced. — But, if you dissolve ammoniacal gas with ice or snow, cold is produced. — Can you account for that?

EMILY.

The gas, being condensed into a liquid, must give out heat; and, on the other hand, the snow or ice, in being rarefied into a liquid, must absorb heat; so that, between the opposite effects, I should

have supposed the original temperature would have been preserved.

MRS. B.

But you have forgotten to take into the account the rarefaction of the water (or melted ice) by the impregnation of the gas; and this is the cause of the cold which is ultimately produced.

CAROLINE.

Is the *sal volatile* (the smell of which so strongly resembles hartshorn) likewise a preparation of ammonia?

MRS. B.

It is carbonate of ammonia dissolved in water; and which, in its concrete state, is commonly called salts of hartshorn. Ammonia is caustic, like the fixed alkalies, as you may judge by the pungent effects of hartshorn, which cannot be taken internally, nor applied to delicate external parts, without being plentifully diluted with water. — Oil and acids are very excellent antidotes for alkaline poisons; can you guess why?

CAROLINE.

Perhaps, because the oil combines with the alkali and forms soap, and thus destroys its caustic properties; and the acid converts it into a compound salt, which, I suppose, is not so pernicious as caustic alkali.

MRS. B.

Precisely so.

Ammoniacal gas, if it be mixed with atmospheric air, and a lighted taper repeatedly plunged into it, will burn with a large flame of a peculiar yellow colour.

EMILY.

But, pray, tell me, can ammonia be procured from this Libyan salt only?

MRS. B.

So far from it, that it is contained in, and may be extracted from, all animal substances whatever. Hydrogen and nitrogen are two of the chief constituents of animal matter; it is therefore not surprising that they should occasionally meet and combine in those proportions which it is supposed compose ammonia. But this alkali is more frequently generated by the spontaneous decomposition of animal substances; the hydrogen and nitrogen gases arising from putrefied bodies combine, and form the volatile alkali.

Muriate of ammonia, instead of being exclusively brought from Libya, as it originally was, is now chiefly prepared in Europe, by chemical processes. Ammonia, although principally extracted from this salt, can also be produced by a great variety of other substances. The horns of cattle, especially those of deer, yield it in abundance; and it is from this circumstance that a solution of ammonia in water has been called hartshorn. It may likewise be procured from wool, flesh, and

bones; — in a word, any animal substance whatever yields it by decomposition.

We shall now lay aside the alkalies, however important the subject may be, till we treat of their combination with acids. The next time we meet we shall examine the earths.

CONVERSATION XIV.

ON EARTHS.

MRS. B.

THE earths, which we are to-day to examine, are nine in number: —

SILEX,	STRONTITES,
ALUMINE,	YTTRIA,
BARYTES,	GLUCINA,
LIME,	ZIRCONIA.
MAGNESIA,	

The last three are of late discovery ; their properties are but imperfectly known ; and, as they have not yet been applied to use, it will be unnecessary to enter into any particulars respecting them : we shall confine our remarks, therefore, to the first five. They are composed, as you have already learnt, of a metallic basis combined with oxygen ; and, from this circumstance, are incombustible.

CAROLINE.

Yet I have seen turf burnt in the country, and

it makes an excellent fire ; the earth becomes red hot, and gives out a very good quantity of heat.

MRS. B.

It is not the earth which burns, my dear, but the roots, grass, and other remnants of vegetables that are intermixed with it. The caloric, which is produced by the combustion of these substances, makes the earth red hot, and this being a bad conductor of heat retains its caloric a long time; but, were you to examine it when cooled, you would find that it had not absorbed one particle of oxygen, nor suffered any alteration from the fire. Earth is, however, from the circumstance just mentioned, an excellent radiator of heat, and owes its utility, when mixed with fuel, solely to that property. It is in this point of view that Count Rumford has recommended balls of incombustible substances to be arranged in fire-places, and mixed with the coals, by which means the caloric disengaged by the combustion of the latter is more perfectly reflected into the room, and an expense of fuel is saved.

EMILY.

I expected the list of earths to be much more considerable. When I think of the immense variety of soils, I am astonished that there is not a greater number of earths to form them.

MRS. B.

You might, indeed, almost limit that number

to four ; for barytes, strontites, and the others of modern discovery, act but so small a part in this great theatre, that they cannot be reckoned as essential to the general construction of the globe. And you must not confine your idea of earths to the formation of soil ; for rock, marble, chalk, slate, sand, flint, and all kinds of stones, from the precious jewels to the commonest pebbles, — in a word, all the immense variety of mineral products, — may be referred to some of these earths, either in a simple state, or combined the one with the other, or blended with other ingredients.

CAROLINE.

Precious stones composed of earth ! That seems very difficult to conceive.

EMILY.

Is it more extraordinary than that the most precious of all jewels, diamond, should be composed of carbon ? But diamond forms an exception, Mrs. B. ; for, though a stone, it is not composed of earth.

MRS. B.

I did not specify the exception, as I knew you were so well acquainted with it. Besides, I would call a diamond a mineral rather than a stone, as the latter term always implies the presence of some earth.

CAROLINE.

I cannot conceive how such coarse materials can be converted into such beautiful productions.

MRS. B.

We are very far from understanding all the secret resources of nature ; but I do not think the spontaneous formation of the crystals, which we call precious stones, one of the phenomena most difficult to comprehend.

By the slow and regular work of ages, perhaps of hundreds of ages, these earths may be gradually dissolved by water, and as gradually deposited by their solvent in the undisturbed process of crystallisation. The regular arrangement of their particles, during their re-union in a solid mass, gives them that brilliancy, transparency, and beauty, for which they are so much admired ; and renders them in appearance so totally different from their rude and primitive ingredients.

CAROLINE.

But how does it happen that they are spontaneously dissolved, and afterwards crystallised ?

MRS. B.

The scarcity of many kinds of crystals, as rubies, emeralds, topazes, &c., shows that their formation is not an operation very commonly carried on in nature. But cannot you imagine that, when water, holding in solution some particles of earth, filters through the crevices of hills or mountains, and at

length falls drop by drop into some cavity, each successive drop may be slowly evaporated, leaving behind it the particle of earth which it held in solution? You know that crystallisation is more regular and perfect, in proportion as the evaporation of the solvent is slow and uniform: nature, therefore, who knows no limit of time, has, in all works of this kind, an infinite advantage over any artist who attempts to imitate such productions.

EMILY.

I can conceive that the arrangement of the particles of earth, during crystallisation, may be such as to occasion transparency, by admitting a free passage to the rays of light; but I cannot understand why crystallised earths should assume such beautiful colours as most of them do. Sapphire, for instance, is of a celestial blue; ruby, a deep red; topaz, a brilliant yellow.

MRS. B.

Nothing is more simple than to suppose that the arrangement of their particles is such as to transmit some of the coloured rays of light, and to reflect others: in which case the stone must appear of the colour of the rays which it reflects. But, besides, it frequently happens that the colour of a stone is owing to the mixture of some metallic matter.

CAROLINE.

Pray, are the different kinds of precious stones

each composed of one individual earth, or are they formed of a combination of several earths?

MRS. B.

A great variety of materials enters into the composition of most of them; not only several earths, but sometimes salts and metals. The earths, however, in their simple state, frequently form very beautiful crystals; and, indeed, it is in that state only that they can be obtained perfectly pure.

EMILY.

Is not the Derbyshire spar produced by the crystallisation of earths, in the way you have just explained? Some of the subterraneous caverns in which it is found are very similar to those you have described.

MRS. B.

Yes; but this spar is but an imperfect specimen of crystallisation: it consists of a variety of ingredients confusedly blended together, as you may judge by its opacity, and by the various colours and appearances which it exhibits.

But, in examining the earths in their most perfect and agreeable form, we must not lose sight of that state in which they are commonly found, and which, if less pleasing to the eye, is far more interesting by its utility.

All the earths are more or less endowed with alkaline properties; but there are four, barytes, magnesia, lime, and strontites, which are called

alkaline earths, because they possess those qualities in so great a degree, as to entitle them, in most respects, to the rank of alkalies. They combine and form compound salts with acids in the same way as alkalies; they are, like them, susceptible of a considerable degree of causticity, and are acted upon in a similar manner by chemical tests. The remaining earths, *silex* and *alumine*, with one or two others of later discovery, are in some degree more earthy; that is to say, they possess more completely the properties common to all the earths, which are, insipidity, dryness, unalterableness in the fire, infusibility, &c.

CAROLINE.

Yet, did you not tell us that *silex*, or siliceous earth, when mixed with an alkali, was fusible, and ran into glass?

MRS. B.

Yes, my dear; but the characteristic properties of earths, which I have mentioned, are to be considered as belonging to them in a state of purity only; a state in which they are very seldom to be met with in nature. Besides these general properties, each earth has its own specific characters, by which it is distinguished from any other substance. Let us, therefore, review them separately.

SILEX, or *SILICA*, abounds in flint, sand, sandstone, agate, jasper, &c.; it forms the basis of many precious stones, and particularly of those which strike fire with steel. It is rough to the

touch, scratches and wears away metals; it is acted upon by no acid but the fluoric, and is not soluble in water by any known process; but nature certainly dissolves it by means with which we are unacquainted, and thus produces a variety of siliceous crystals, and amongst these *rock crystal*, which is the purest specimen of this earth. Silix appears to have been intended by Providence to form the solid basis of the globe, to serve as a foundation for the original mountains, and give them that hardness and durability which has enabled them to resist the various revolutions which the surface of the earth has successively undergone. From these mountains, siliceous rocks have, during the course of ages, been gradually detached by torrents of water, and brought down in fragments: these, in the violence and rapidity of their descent, are sometimes crumbled to sand, and in this state form the beds of rivers and of the sea, chiefly composed of siliceous materials. Sometimes the fragments are broken without being pulverised by their fall, and assume the form of pebbles, which gradually become rounded and polished.

EMILY.

Pray, what is the true colour of silix, which forms such a variety of different-coloured substances? Sand is brown, flint is nearly black, and precious stones are of all colours.

MRS. B.

Pure silix, such as is found only in the chemist's

laboratory, is perfectly white; and the various colours which it assumes, in the different substances you have mentioned, proceed from the different ingredients with which it is mixed in them.

CAROLINE.

I wonder that silex is not more valuable, since it forms the basis of so many precious stones.

MRS. B.

You must not forget that the value we set upon precious stones depends, in a great measure, upon the scarcity with which nature affords them; for, were those productions either common or perfectly imitable by art, they would no longer, notwithstanding their beauty, be so highly esteemed. But the real value of siliceous earth, in many of the most useful arts, is very extensive. Mixed with clay, it forms the basis of all the various kinds of earthenware, from the most common utensils to the most refined ornaments.

EMILY.

And we must recollect its importance in the formation of glass with potash.

MRS. B.

Nor should we omit to mention, likewise, many other important uses of silex, such as being the chief ingredient of some of the most durable cements, of mortar, &c.

I said before, that siliceous earth combined with

no acid but the fluoric; it is for this reason that glass is liable to be attacked by that acid only, which, from its strong affinity to silex, forces that substance from its combination with the potash, and thus destroys the glass.

We will now hasten to proceed to the other earths, for I am rather apprehensive of your growing weary of this part of our subject.

CAROLINE.

I confess that the history of the earths is not quite so entertaining as that of the simple substances.

MRS. B.

Perhaps not; but they form the basis of so many interesting and important compounds, that their omission would throw great obscurity on our general outline of chemical science. We shall, however, review them in as cursory a manner as the subject will admit of.

ALUMINE derives its name from a compound salt called *alum*, of which it forms the basis.

CAROLINE.

But it ought to be just the contrary, Mrs. B.; the simple body should give, instead of taking, its name from the compound.

MRS. B.

That is true; but, as the compound salt was known long before its basis was discovered, it was very natural that, when the earth was at length separated from the acid, it should derive its name

from the compound from which it was obtained. However, to remove your scruples, we will call the salt, according to the new nomenclature, *sulphate of alumine*. From this combination alumine may be obtained in its pure state; it is then soft to the touch, makes a paste with water, and hardens in the fire. In nature, it is found chiefly in clay, which contains a considerable proportion of this earth; it is very abundant in fullers' earth, slate, and a variety of other mineral productions. There is, indeed, scarcely any mineral substance more useful to mankind than alumine. In the state of clay, it forms large strata of the earth, gives consistency to the soil of valleys, and of all low and damp spots, such as swamps and marshes. The beds of lakes, ponds, and springs, are almost entirely of clay: instead of allowing of the filtration of water, as sand does, it forms an impenetrable bottom, and by this means water is accumulated in the caverns of the earth, producing those reservoirs whence springs issue, and spout out at the surface.

EMILY.

I always thought that these subterraneous reservoirs of water were bedded by some hard stone, or rock, which the water could not penetrate.

MRS. B.

That is not the case; for in the course of time water would penetrate or wear away silex, or any

other kind of stone, while it is effectually stopped by clay or alumine.

The solid compact soils, such as are fit for corn, owe their consistence in a great measure to alumine; this earth is, therefore, used to improve sandy or chalky soils, which do not retain a sufficient quantity of water for the purpose of vegetation.

Alumine is the most essential ingredient in all potteries. It enters into the composition of brick, as well as that of the finest porcelain; the addition of silex and water hardens it, renders it susceptible of a degree of vitrification, and makes it perfectly fit for its various purposes.

CAROLINE.

I can scarcely conceive that brick and china should be made of the same materials.

MRS. B.

Brick consists almost entirely of baked clay; but a certain proportion of silex is essential to the formation of earthen or stone ware. In common potteries sand is used for that purpose; a more pure silex is, I believe, necessary for the composition of porcelain, as well as a finer kind of clay; and these materials are, no doubt, more carefully prepared and curiously wrought in the one case than in the other. Porcelain owes its beautiful semitransparency to a commencement of vitrification.

EMILY.

But the commonest earthenware, though not transparent, is covered with a kind of glazing.

MRS. B.

That precaution is equally necessary for use as for beauty, as the ware would be liable to be spoiled and corroded by a variety of substances, if not covered with a coating of this kind. In porcelain it consists of enamel, which is a fine white opaque glass, formed of metallic oxides, sand, salts, and such other materials as are susceptible of vitrification. The glazing of common earthenware is made chiefly of oxide of lead, or sometimes merely of salt, which, when thinly spread over earthen vessels, will, at a certain heat, run into opaque glass.

CAROLINE.

And of what nature are the colours which are used for painting porcelain?

MRS. B.

They are all composed of metallic oxides; so that these colours, instead of receiving injury from the application of fire, are strengthened and developed by its action, which causes them to undergo different degrees of oxidation.

Alumine and silex are not only often combined by art, but they have in nature a very strong tendency to unite, and are found combined, in different proportions, in various gems and other

minerals. Indeed, many of the precious stones, such as ruby, oriental sapphire, amethyst, &c., consist chiefly of alumine.

We may now proceed to the alkaline earths. I shall say but a few words on BARYTES, as it is hardly ever used, except in chemical laboratories. It is remarkable for its great weight, and its strong alkaline properties, such as destroying animal substances, turning green some blue vegetable colours, and showing a powerful attraction for acids. This last property it possesses to such a degree, particularly with regard to the sulphuric acid, that it will always detect its presence in any substance or combination whatever, by immediately uniting with it, and forming a sulphate of barytes. This renders it a very valuable chemical test. It is found pretty abundantly in nature in the state of carbonate, from which the pure earth can be easily separated.

The next earth we have to consider is LIME. This is a substance of too great and general importance to be passed over so lightly as the last.

Lime is strongly alkaline. In nature it is not met with in its simple state, as its affinity for water and carbonic acid is so great that it is always found combined with these substances, with which it forms the common limestone; but it is separated in the kiln from these ingredients, which are volatilised whenever a sufficient degree of heat is applied.

EMILY.

Pure lime, then, is nothing but limestone, which has been deprived, in the kiln, of its water and carbonic acid?

MRS. B.

Precisely: in this state it is called *quick-lime*, and it is so caustic that it is capable of decomposing the dead bodies of animals very rapidly, without their undergoing the process of putrefaction. — I have here some quick-lime, which is kept carefully corked up in a bottle, to prevent the access of air; for, were it at all exposed to the atmosphere, it would absorb both moisture and carbonic acid gas from it, and soon be slaked. Here is also some limestone: we shall pour a little water on each, and observe the different effects that result from it.

CAROLINE.

How the quick-lime hisses! It is become excessively hot! — It swells, and now it bursts and crumbles to powder, while the water appears to produce no kind of alteration on the limestone.

MRS. B.

Because the limestone is already saturated with water; whilst the quick-lime, which has been deprived of it in the kiln, combines with it with very great avidity, and produces this prodigious disengagement of heat, the cause of which I formerly explained to you: — do you recollect it?

EMILY.

Yes; you said that the heat did not proceed from the lime, but from the water, which, in becoming solid, parted with its heat of liquidity.

MRS. B.

Very well. If we continue to add successive quantities of water to the lime, after being slaked and crumbled, as you see, it will then gradually be diffused in the water, till it will at length be dissolved in it, and entirely disappear; but for this purpose it requires no less than 700 times its weight of water. This solution is called *lime-water*.

CAROLINE.

How very small, then, is the proportion of lime dissolved!

MRS. B.

Barytes is also of very difficult solution; but it is much more soluble in the state of crystals. The liquid contained in this bottle is lime-water: it is often used as a medicine; chiefly, I believe, for the purpose of combining with, and neutralising, the superabundant acid which it meets with in the stomach.

EMILY.

I am surprised that it is so perfectly clear: it does not at all partake of the whiteness of the lime.

MRS. B.

Have you forgotten that, in solutions, the solid body is so minutely subdivided by the fluid as to

become invisible, and therefore, will not in the least degree impair the transparency of the solvent?

I said that the attraction of lime for carbonic acid was so strong that it would absorb it from the atmosphere. We may see this effect by exposing a glass of lime-water to the air: the lime will then separate from the water, combine with the carbonic acid, and re-appear on the surface in the form of a white film, which is carbonate of lime, commonly called *chalk*.

CAROLINE.

Chalk is, then, a compound salt ! I never should have supposed that those immense beds of chalk, which we see in many parts of the country, were a salt. Now the white film begins to appear on the surface of the water ; but it is far from resembling hard solid chalk.

MRS. B.

That is owing to its state of extreme division : in a little time it will collect into a more compact mass, and subside at the bottom of the glass.

If you breathe into lime-water, the carbonic acid, which is mixed with the air that you expire, will produce the same effect. It is an experiment very easily made. I shall pour some lime-water into this glass tube, and, by breathing repeatedly into it, you will soon perceive a precipitation of chalk.

EMILY.

I see already a small white cloud formed.

MRS. B.

It is composed of minute particles of chalk; at present it floats in the water, but it will soon subside.

Carbonate of lime, or chalk, you see, is insoluble in water, since the lime which was dissolved reappears when converted into chalk; but you must take notice of a very singular circumstance, which is, that chalk is soluble in water impregnated with carbonic acid.

CAROLINE.

It is very curious, indeed, that carbonic acid gas should render lime soluble in one instance, and insoluble in the other.

MRS. B.

I have here a bottle of Seltzer water, which, you know, is strongly impregnated with carbonic acid: — let us pour a little of it into a glass of lime-water. You see that it immediately forms a precipitation of carbonate of lime?

EMILY.

Yes, a white cloud appears.

MRS. B.

I shall now pour an additional quantity of the Seltzer water into the lime-water.

EMILY.

How singular! The cloud is re-dissolved, and the liquid is again transparent.

MRS. B.

All the mystery depends upon this circumstance, that carbonate of lime is soluble in carbonic acid, whilst it is insoluble in water: the first quantity of carbonic acid, therefore, which I introduced into the lime-water, was employed in forming the carbonate of lime, which remained visible until an additional quantity of carbonic acid dissolved it. Thus, you see, when the lime and carbonic acid are in such proportions as to form chalk, the white cloud appears; but when the acid predominates, the chalk is no sooner formed than it is dissolved.

CAROLINE.

That is now the case: but let us try whether a further addition of lime-water will again precipitate the chalk.

EMILY.

It does, indeed! The cloud re-appears, because, I suppose, there is now no more of the carbonic acid than is necessary to form chalk; and, in order to dissolve the chalk, a superabundance of acid is required.

MRS. B.

We have, I think, carried this experiment far enough: every repetition would but exhibit the same appearances.

Lime combines with most of the acids, to which the carbonic (as being the weakest) readily yields it; but these combinations we shall have an oppor-

tunity of noticing more particularly hereafter. It unites with phosphorus and with sulphur in their simple state: in short, of all the earths, lime is that which nature employs most frequently, and most abundantly, in its innumerable combinations. It is the basis of all calcareous earths and stones; we find it likewise in the animal and the vegetable creations.

EMILY.

And in the arts is not lime of very great utility?

MRS. B.

There is scarcely any substance more so: you know that it is a most essential requisite in building, as it constitutes the basis of all cements, such as mortar, stucco, plaster, &c.

Lime is also of infinite importance in agriculture: it lightens and warms soils that are too cold and compact, in consequence of too great a proportion of clay. — But it would be endless to enumerate the various purposes for which it is employed; and you know enough of it to form some idea of its importance. We shall, therefore, now proceed to the third alkaline earth, MAGNESIA.

CAROLINE.

We are already in some measure acquainted with that earth: it is a medicine.

MRS. B.

It is in the state of carbonate that magnesia is usually employed medicinally: it then differs but

little in appearance from its simple form, which is that of a very fine light white powder. It dissolves in 2000 times its weight of water, but forms with acids extremely soluble salts. It has not so great an attraction for acids as lime, and consequently yields them to the latter. It is found in a great variety of mineral combinations, such as slate, mica, amianthus, and more particularly in a certain limestone, which was discovered by Mr. Tennant to contain it in very great quantities. It does not attract and solidify water, like lime: but when mixed with water, and exposed to the atmosphere, it slowly absorbs carbonic acid from the latter, and thus loses its causticity. Its chief use in medicine is, like that of lime, derived from its readiness to combine with, and neutralise, the acid which it meets with in the stomach.

EMILY.

Yet you said that it was taken in the state of carbonate, in which case it has already combined with an acid?

MRS. B.

Yes; but the carbonic is the last of all the acids in the order of affinities: it will therefore yield the magnesia to any of the others. It is, however, frequently taken in its caustic state as a remedy for flatulence. Combined with sulphuric acid, magnesia forms another and more powerful medicine, commonly called *Epsom salt*.

CAROLINE.

And, properly, *sulphate of magnesia*, I suppose? Pray, how did it obtain the name of Epsom salt?

MRS. B.

Because there is a spring in the neighbourhood of Epsom, which contains this salt in great abundance.

The last alkaline earth which we have to mention is STRONTIAN or STRONTITES, discovered some years ago by Dr. Hope. It so strongly resembles barytes in its properties, and is so sparingly found in nature, and of so little use in the arts, that it will not be necessary to enter into any particulars respecting it. One of the remarkable characteristic properties of strontites is, that its salts, when dissolved in spirit of wine, tinge the flame of a deep red, or blood colour.

CONVERSATION XV.

ON ACIDS.

MRS. B.

WE may now proceed to the acids. Of the metallic oxides you have already acquired some general notions. This subject, though highly interesting in its details, is not of sufficient importance to our concise view of chemistry, to be particularly treated of; but it is absolutely necessary that you should be better acquainted with the acids, and likewise with their combinations with the alkalies, which form the triple compounds, called NEUTRAL SALTS.

The class of acids is characterised by very distinct properties. They all change blue vegetable infusions to a red colour: they are all more or less sour to the taste; and have a general tendency to combine with the earths, alkalies, and metallic oxides.

You have, I believe, a clear idea of the nomenclature by which the base (or radical) of the acid, and the various degrees of acidification, are expressed?

EMILY.

Yes, I think so; the acid is distinguished by the name of its base, and its degree of oxidation, that is, the quantity of oxygen it contains by the termination of that name in *ous* or *ic*; thus sulphurous acid is formed by the smallest proportion of oxygen combined with sulphur; while sulphuric acid results from the combination of sulphur with the greatest quantity of oxygen.

MRS. B.

A still greater latitude may, in many cases, be allowed to the proportions of oxygen which can be combined with acidifiable radicals; for several of these radicals are susceptible of uniting with a quantity of oxygen so small as to be insufficient to give them the properties of acids; in these cases, therefore, they are converted into oxides. Such is sulphur, which, by exposure to the atmosphere with a degree of heat inadequate to produce inflammation, absorbs a small proportion of oxygen, which colours it red or brown. This, therefore, may be considered as a first degree of oxygenation of sulphur: the second converts it into sulphurous acid; the third into the sulphuric acid; and, fourthly, if it were found capable of combining with a still larger proportion of oxygen, it would then be termed *superoxygenated sulphuric acid*.

EMILY.

Are these various degrees of oxygenation common to all the acids?

MRS. B.

No; they vary much in this respect : some are susceptible of only one degree of oxygenation ; others, of two, or three ; there are but very few that will admit of more.

CAROLINE.

The modern nomenclature must be of immense advantage in pointing out so easily the nature of the acids, and their various degrees of oxygenation.

MRS. B.

Till lately many of the acids had not been decomposed ; but analogy afforded so strong a proof of their compound nature, that I never could reconcile myself to classing them with the simple bodies, though this division has been adopted by several chemical writers.

CAROLINE.

We have heard of a great variety of acids ; pray how many are there in all ?

MRS. B.

I believe there are reckoned to be at present above forty, and their number is constantly increasing as the science improves ; but the most important, and those to which we shall almost entirely confine our attention, are but few. I shall, however, begin by giving you a general view of the whole.

This class of bodies was formerly divided into mineral, vegetable, and animal acids, according to the substances from which they were commonly obtained.

CAROLINE.

That, I should think, must have been an excellent arrangement: why was it altered?

MRS. B.

Because, in many cases, it produced confusion. In which class, for instance, would you place carbonic acid?

CAROLINE.

Now I perceive the difficulty. As you have told us that it exists in the animal, vegetable, and mineral kingdoms, I should be much at a loss where to place it.

EMILY.

There would be the same objection with respect to phosphoric acid, which, though obtained chiefly from bones, can also, you said, be found in small quantities in stones, and likewise in some plants.

MRS. B.

You see, therefore, the propriety of changing this mode of classification. These objections do not exist in the present nomenclature; for the composition and nature of each individual acid is in some degree pointed out, instead of the class of bodies from which it is extracted; and, with regard to the more general division of acids, they are classed under these three heads: —

1st. Acids of known or supposed simple bases, which are formed by the union of these bases with oxygen. They are the following: —

The <i>Sulphuric</i>	}	Acids of known and simple bases.
<i>Carbonic</i>		
<i>Nitric</i>		
<i>Phosphoric</i>		
<i>Arsenical</i>		
<i>Tungstenic</i>		
<i>Molybdenic</i>		
<i>Boracic</i>		
<i>Fluoric</i>		
<i>Muriatic</i>		

This class comprehends the most anciently known and most important acids. The sulphuric, nitric, and muriatic, were formerly, and are still frequently, called *mineral acids*.

2dly. Acids that have double or binary radicals, and which consequently consist of triple combinations. These are the vegetable acids, whose common radical is a compound of hydrogen and carbon.

CAROLINE.

But if the basis of all the vegetable acids be the same, it should form but one acid; it may indeed combine with different proportions of oxygen, but the nature of the acid must be the same.

MRS. B.

The only difference that exists in the basis of

vegetable acids, is the various proportions of hydrogen and carbon of which they are severally composed. But this is cause enough to produce a number of acids apparently very dissimilar. That they do not, however, differ essentially, is proved by their susceptibility of being converted into each other by the addition or subtraction of a portion of hydrogen or of carbon. The names of these acids are, —

The *Acetic*

Oxalic

Tartaric

Citric

Malic

Gallic

Mucous

Benzoic

Succinic

Camphoric

Suberic

Moroxalic

Boletic

Kinic

Pyro-tartaric

Pyro-citric

Pyro-malic

Acids of double bases, being
of vegetable origin.*

* There are many other acids of less importance, discovered recently, which are not included in the above tables.

The 3d class of acids consists of those which have triple bases, and are therefore of a still more compound nature. This class comprehends the animal acids, which are,—

The <i>Lactic</i>	}	Acids of triple bases, or animal acids.
<i>Caseic</i>		
<i>Prussic</i>		
<i>Formic</i>		
<i>Bombic</i>		
<i>Cetic</i>		
<i>Sebacic</i>		
<i>Margaritic</i>		
<i>Oleic</i>		
<i>Zoonic</i>		
<i>Lithic</i>		

I have given you this summary account or enumeration of the acids, as you may find it more satisfactory to have at once an outline or a general notion of the extent of the subject; but we shall now confine ourselves to the first class, which requires our more immediate attention; and defer the few remarks which we shall have to make on the others, till we treat of the chemistry of the animal and vegetable kingdoms.

The acids of simple and known radicals are in most instances capable of being decomposed by combustible bodies, to which they yield their oxygen. If, for instance, I pour a drop of sulphuric acid on this piece of iron it will produce a spot of rust; — you know what that is?

CAROLINE.

Yes; it is an oxide, formed by the oxygen of the acid combining with the iron.

MRS. B.

In this case, you see, the sulphur deposits the oxygen by which it was acidified on the metal. And, again, if we pour some acid on a compound combustible substance (we shall try it on this piece of wood), it will combine with one or more of the constituents of that substance, and occasion a decomposition.

EMILY.

It has changed the colour of the wood to black. How is that?

MRS. B.

The oxygen deposited by the acid has burnt it: you know that wood in burning becomes black before it is reduced to ashes. Whether it derives the oxygen which burns it from the atmosphere, or from any other source, the chemical effect on the wood is the same. In the case of real combustion, wood becomes black, because it is reduced to the state of charcoal by the evaporation of its other constituents. But can you tell me the reason why wood turns black when burnt by the application of an acid?

CAROLINE.

I must first inquire what are the ingredients of wood?

MRS. B.

Hydrogen and carbon are the chief constituents of wood, as of all other vegetable substances.

CAROLINE.

Well, then, I suppose that the oxygen of the acid combines with the hydrogen of the wood, to form water: and that the carbon of the wood, remaining alone, appears of its usual black colour.

MRS. B.

Very well, my dear; that is certainly a plausible explanation.

EMILY.

Would not this be a good method of making charcoal?

MRS. B.

It would be an extremely expensive, and, I believe, very imperfect method; for the action of the acid on the wood, and the heat produced by it, are far from sufficient to deprive the wood of all its evaporable parts.

CAROLINE.

What is the reason that vinegar, lemon, and the acid of fruits, do not produce this effect on wood?

MRS. B.

They are vegetable acids, whose bases are composed of hydrogen and carbon; the oxygen, therefore, will not be disposed to quit this radical, where it is already united with hydrogen. The strongest of these may, perhaps, yield a little of their oxygen

to the wood, and produce a stain upon it; but the carbon will not be sufficiently uncovered to assume its black colour. Indeed, the several mineral acids themselves possess this power of charring wood in very different degrees.

EMILY.

Cannot vegetable acids be decomposed by any combustibles?

MRS. B.

No; because their radical is composed of two substances which have a greater attraction for oxygen than any known body.

CAROLINE.

And are those strong acids, which burn and decompose wood, capable of producing similar effects on the skin and flesh of animals?

MRS. B.

Yes; all the mineral acids, and one of them more especially, possess powerfully caustic qualities. They actually corrode and destroy the skin and flesh; but they do not produce upon these exactly the same alteration they do on wood, probably because there is a great proportion of nitrogen and other substances in animal matter, which prevents the separation of carbon from being so conspicuous. We shall here conclude our general view of the acids.

CONVERSATION XVI.

OF THE SULPHURIC AND PHOSPHORIC ACIDS, OR THE COMBINATIONS OF OXYGEN WITH SULPHUR AND PHOSPHORUS; AND OF THE SULPHATES AND PHOSPHATES.

MRS. B.

IN addition to the general survey which we have taken of acids, I think you will find it interesting to examine individually a few of the most important of them, and likewise some of their principal combinations with the alkalies, alkaline earths, and metals. The first of the acids, in point of importance, is the SULPHURIC, formerly called *oil of vitriol*.

CAROLINE.

I have known it a long time by that name, but had no idea that it was the same fluid as sulphuric acid. What resemblance or connection can there be between oil of vitriol and this acid?

MRS. B.

Vitriol is the common name for sulphate of iron, a salt which is formed by the combination of sulphuric acid and iron: the sulphuric acid was for-

merly obtained by distillation from this salt, and it very naturally received its name from the substance which afforded it.

CAROLINE.

But is it still commonly called oil of vitriol?

MRS. B.

Frequently; a sufficient length of time has not yet elapsed since the invention of the new nomenclature for it to be generally disseminated; but, as it is adopted by all scientific chemists, there is every reason to suppose that it will gradually become universal. When I received this bottle from the chemists, *oil of vitriol* was inscribed on the label; but as I knew you were very punctilious in regard to the nomenclature, I changed it, and substituted the words *sulphuric acid*.

EMILY.

This acid has neither colour nor smell, but it appears much thicker than water.

MRS. B.

It is nearly twice as heavy as water, and has, you see, an oily consistence.

CAROLINE.

And it is probably from this circumstance that it has been called an oil; for it can have no real claim to that name, as it does not contain either hydrogen or carbon, which are the essential constituents of oil.

MRS. B.

Certainly : and, therefore, it would be the more absurd to retain a name which owed its origin to such a mistaken analogy.

Sulphuric acid, in its purest state, would probably be a concrete substance, but its attraction for water is such, that it is impossible to obtain this acid perfectly free from it ; it is, therefore, always seen in a liquid form, such as you here find it. One of the most striking properties of sulphuric acid is that of evolving a considerable quantity of heat when mixed with water : this I have already shown you.

EMILY.

Yes, I recollect it ; but what was the degree of heat produced by that mixture ?

MRS. B.

The thermometer may be raised by it to 300 degrees, which is considerably above the temperature of boiling water.

CAROLINE.

Then water might be made to boil in that mixture ?

MRS. B.

Nothing more easy, provided that you employ sufficient quantities of acid and of water, and in the due proportions. The greatest heat is produced by a mixture of one part of water to four of the acid : we shall make a mixture of these pro-

portions, and immerse in it this thin glass tube, which is full of water.

CAROLINE.

The vessel feels extremely hot, but the water does not boil yet.

MRS. B.

You must allow some time for the heat to penetrate the tube, and raise the temperature of the water to the boiling point.

CAROLINE.

Now it boils—and with increasing violence.

MRS. B.

But it will not continue boiling long; for the mixture gives out heat only while the particles of the water and the acid are mutually penetrating each other; as soon as the new arrangement of these particles is effected, the mixture will gradually cool, and the water return to its former temperature.

You have seen the manner in which sulphuric acid decomposes all combustible substances, whether animal, vegetable, or mineral, and burns them by means of its oxygen?

CAROLINE.

I have very unintentionally repeated the experiment on my gown, by letting a drop of the acid fall upon it, and it has made a stain, which, I suppose, will never wash out.

MRS. B.

No, certainly; for before you can put it into water the spot will become a hole, as the acid has literally burnt the muslin.

CAROLINE.

So it has, indeed! Well, I will fasten the stopper, and put the bottle away, for it is a dangerous substance. — Oh, now I have done worse still, for I have spilt some on my hand!

MRS. B.

It is then burnt, as well as your gown, for you know that oxygen destroys animal as well as vegetable matter; and as far as the decomposition of the skin of your finger is affected, there is no remedy; but by washing it immediately in water, you will dilute the acid, and prevent any farther injury.

CAROLINE.

It feels extremely hot, I assure you.

MRS. B.

You have now learned, by experience, how cautiously this acid must be used. You will soon become acquainted with another acid, the nitric, which, though it produces less heat on the skin, destroys it still quicker, and makes upon it an indelible stain. You should never handle any substances of this kind without previously dipping your fingers in water, which will weaken the caustic effects of the acid. But, since you will not

repeat the experiment, I must put in the stopper, for the acid attracts the moisture from the atmosphere, which destroys its strength and purity.

EMILY.

Pray, how can sulphuric acid be extracted from sulphate of iron by distillation?

MRS. B.

The process of distillation, you know, consists in separating substances from one another by means of their different degrees of volatility, and by the introduction of a new chemical agent, caloric. Thus, if sulphate of iron be exposed in a retort to a proper degree of heat, it will be decomposed, and the sulphuric acid will be volatilised.

EMILY.

But now that the process of forming acids by the combustion of their radicals is known, why should not this method be used for making sulphuric acid?

MRS. B.

This is actually done in most manufactures; but the usual method of preparing sulphuric acid does not consist in burning the sulphur in oxygen gas (as we formerly did by way of experiment), but in heating it together with another substance, nitre, which yields oxygen in sufficient abundance to render the combustion in common air rapid and complete.

CAROLINE.

This substance, then, answers the same purpose as oxygen gas?

MRS. B.

Exactly. In manufactures the combustion is performed in a leaden chamber, with water at the bottom, to receive the vapour and assist its condensation. The combustion is, however, never so perfect but that a quantity of *sulphurous* acid is formed at the same time; for you recollect that the sulphurous acid, according to the chemical nomenclature, differs from the sulphuric only by containing less oxygen.

From its own powerful properties, and from the various combinations into which it enters, sulphuric acid is of great importance in many of the arts.

It is used also in medicine in a state of great dilution; for were it taken internally, in a concentrated state, it would prove a most dangerous poison.

CAROLINE.

I am sure it would burn the throat and stomach.

MRS. B.

Can you think of any thing that would prove an antidote to this poison?

CAROLINE.

A large draught of water to dilute it.

MRS. B.

That would certainly weaken the caustic power of the acid, but it would increase the heat to an intolerable degree. Do you recollect nothing that would destroy its deleterious properties more effectually?

EMILY.

An alkali might, by combining with it: but then, a pure alkali is itself a poison, on account of its causticity.

MRS. B.

There is no necessity that the alkali should be caustic. Soap, in which it is combined with oil; or magnesia, either in a state of carbonate, or mixed with water, would prove the best antidote.

EMILY.

In those cases, then, I suppose, the potash and the magnesia would quit their combinations to form salts with the sulphuric acid?

MRS. B.

Precisely.

We may now make a few observations on the sulphurous acid, which we have found to be the product of sulphur slowly and imperfectly burnt. This acid is not like the sulphuric, a liquid; it is naturally of a gaseous form, but may be condensed into a liquid by intense cold. It is also distinguished by its pungent smell.

CAROLINE.

Its aëriform state is, I suppose, owing to the smaller proportion of oxygen, which renders it lighter than sulphuric acid?

MRS. B.

Probably; for, by adding oxygen to the weaker acid, it may be converted into the stronger kind. But this change of state may also be connected with a change of affinity with regard to caloric.

EMILY.

And may sulphurous acid be obtained from sulphuric acid by a diminution of oxygen?

MRS. B.

Yes; it can be done by bringing any combustible substance in contact with the acid. This decomposition is most easily performed by some of the metals; these absorb a portion of the oxygen from the sulphuric acid, which is thus converted into the sulphurous, and flies off in its gaseous form.

CAROLINE.

And can the sulphurous acid itself be decomposed and reduced to sulphur?

MRS. B.

Yes; if this gas be heated in contact with charcoal, the oxygen of the gas will combine with it, and the pure sulphur will be regenerated.

Sulphurous acid is readily absorbed by water; and in this liquid state it is found particularly use-

ful in bleaching linen and woollen cloths, and is much used in manufactures for those purposes. I can show you its effect in destroying colours, by taking out vegetable stains. — I think I see a spot on your gown, Emily, on which we may try the experiment.

EMILY.

It is the stain of mulberries; but I shall be almost afraid of exposing my gown to the experiment, after seeing the effect which the sulphuric acid produced on that of Caroline —

MRS. B.

There is no such danger from the sulphurous; but the experiment must be made with great caution, for during the formation of sulphurous acid by combustion there is always some sulphuric produced.

CAROLINE.

But where is your sulphurous acid?

MRS. B.

We may easily prepare some ourselves simply by burning a match; we must first wet the stain with water, and now hold it in this way, at a little distance, over the lighted match: the vapour that arises from it is sulphurous acid, and the stain, you see, gradually disappears.

EMILY.

I have frequently taken out stains by this means, without understanding the nature of the process.

But why is it necessary to wet the stain before it is exposed to the acid fumes?

MRS. B.

The moisture attracts and absorbs the sulphurous acid; and it serves likewise to dilute any particles of sulphuric acid which might injure the linen.

I will show you a curious effect of the rapid evaporation of sulphurous acid, which you will understand very well if you recollect the theory of latent heat.

CAROLINE.

Oh! yes; that we do. When a solid body becomes liquid, or a liquid becomes gas, heat is absorbed by the body which changes its state;—whilst, on the contrary, when a gaseous body becomes liquid, or a liquid becomes solid, heat is given out.

MRS. B.

I am glad to find you remember the theory of latent heat so well. Now for our experiment.

Here is a ladle of platina, which has been made red hot by holding it over this lamp. I will pour some water into it, and you will observe what happens.

EMILY.

The water already begins to simmer, but more slowly than I should have expected in such a hot ladle.

MRS. B.

Now I will pour upon the water in the ladle some sulphurous acid which has been reduced to a liquid by intense cold. What do you suppose will take place?

EMILY.

The sulphurous acid, being exposed to the heat of the ladle, will immediately resume its gaseous state, and evaporate. But what is this! A lump of ice remains in the ladle, and the water has disappeared; it must have been frozen?

MRS. B.

It has; the sulphurous acid no sooner came in contact with the water in the ladle, than it absorbed the whole of its latent heat, evaporated in the form of an invisible gas, and left the water converted into ice.

CAROLINE.

Well, I think this is the most curious thing you have yet shown us, a lump of ice frozen in a red-hot ladle! You did well to throw it out of the ladle, Mrs. B., for it would not have remained there without melting.

EMILY.

This is indeed astonishing. It is then the latent heat, passing from the water into the sulphurous acid, which performs all these wonders?

MRS. B.

Yes; the liquid acid is changed into a gas by the acquisition of caloric, and the water into ice by the loss of it.

CAROLINE.

I wonder that the heat of the ladle did not prevent the water from freezing.

MRS. B.

The great heat of the ladle converts all the water which is in immediate contact with it into steam; consequently a layer of steam is interposed between the lower surface of the water and the ladle, and as steam is a very bad conductor of heat, the caloric of the ladle has some difficulty in reaching the water.

EMILY.

And is there a layer of steam at the bottom of the tea-kettle when it boils?

MRS. B.

No; this occurs only when the vessel is heated beyond the boiling point of the liquid it contains, as is the case with the ladle. Under ordinary circumstances bubbles of vapour are formed at the bottom of the boiling liquid, and rise to the surface, where they evaporate.

Sulphur appears to be susceptible of a third combination with oxygen, in which the proportion of the latter is too small to render the sulphur

acid. It acquires this slight oxygenation by mere exposure to the atmosphere, without any application of heat: in this case, the sulphur does not change its natural form, but is only discoloured, being changed to red or brown, a state in which it may be considered as an oxide of sulphur.

Before we take leave of sulphuric acid, I will tell you some of its principal combinations. It unites with all the alkalies, alkaline earths, and metals, to form compound salts.

CAROLINE.

Pray, give me leave to interrupt you for a moment: you have never mentioned any other salts than the compound or neutral salts: is there no other kind?

MRS. B.

The term *salt* has been used, from time immemorial, as a kind of general name for any substance that has savour, odour, is soluble in water, and crystallisable, whether it be of an acid, an alkaline, or compound nature; but the compound salts alone retain that appellation in modern chemistry.

The most important of the salts formed by the combinations of the sulphuric acid are, first, *sulphate of potash*: this is a very bitter salt, much used in medicine. It is found in the ashes of most vegetables; but it may be prepared artificially by the immediate combination of sulphuric acid and potash. This salt is easily soluble in boiling water.

Solubility is, indeed, a property common to all salts; and they always produce cold in melting.

EMILY.

Which must be owing to the caloric they absorb in passing from a solid to a fluid form.

MRS. B.

That is, certainly, the most probable explanation.

Sulphate of soda, commonly called Glauber's salt, is another medicinal salt, which is still more bitter than the preceding. We must prepare some of these compounds, that you may observe the phenomena which take place during their formation. We need only pour some sulphuric acid over the soda which I have put into this glass.

CAROLINE.

What an amazing heat is disengaged!—I thought you said that cold was produced by the melting of salts?

MRS. B.

But you must observe that we are now *making*, not *melting* a salt. Heat is disengaged during the formation of compound salts, and a faint light is also emitted, which may sometimes be perceived in the dark.

CAROLINE.

Will this sulphate of soda become solid?

MRS. B.

We have, probably, not mixed the acid and

the alkali in the exact proportions which are required for the formation of the salt, otherwise the mixture would have been almost immediately changed to a solid mass; but, in order to obtain it in crystals, as you see it in this bottle, it would be necessary first to dilute it with water, and afterwards to evaporate the water, during which operation the salts would gradually crystallise.

CAROLINE.

But of what use is the addition of water, if it is afterwards to be evaporated?

MRS. B.

When suspended in water, the acid and the alkali are more at liberty to act on each other, their union is more complete, and the salt assumes the regular form of crystals during the slow evaporation of its solvent.

Sulphate of soda liquefies by heat, and effloresces in the air.

EMILY.

Pray, what is the meaning of the word *effloresces*? I do not recollect your having mentioned it before.

MRS. B.

A salt is said to effloresce when it loses its water of crystallisation on being exposed to the atmosphere, and is thus gradually converted into a dry powder: you may observe that these crystals of sulphate of soda are far from possessing the transparency which belongs to their crystalline state;

they are covered with a white powder, occasioned by their having been exposed to the atmosphere, which has deprived their surface of its lustre, by absorbing its water of crystallisation. Salts are, in general, either *efflorescent* or *deliquescent*: this latter property is precisely the reverse of the former; that is to say, deliquescent salts absorb water from the atmosphere, and are moistened and gradually melted by it. Muriate of lime is an instance of great deliquescence.

EMILY.

But are there no salts that have the same degree of attraction for water as the atmosphere, and which will consequently not be affected by it?

MRS. B.

Yes: there are many such salts; as, for instance, common salt, sulphate of magnesia, and a variety of others.

Sulphate of lime is very frequently met with in nature, and constitutes the well-known substance called *gypsum* or *plaster of Paris*.

Sulphate of magnesia, commonly called *Epsom salt*, is another very bitter medicine, which is obtained from sea-water and from several springs, or may be prepared by the direct combination of its ingredients.

We have formerly mentioned *sulphate of alumine* as constituting the common *alum*: it is found in nature chiefly in the neighbourhood of volcanoes,

and is particularly useful in the arts, from its strong stringent qualities. It is chiefly employed by dyers and calico-printers, to fix colours; and is used also in the manufacture of some kinds of leather.

Sulphuric acid combines likewise with the metals.

CAROLINE.

One of these combinations, *sulphate of iron*, we are already well acquainted with.

MRS. B.

That is the most important metallic salt formed by sulphuric acid, and the only one that we shall here notice. It is of great use in the arts; and, in medicine, it affords a very valuable tonic: it is of this salt that most of those preparations called *steel medicines* are composed.

CAROLINE.

But does any carbon enter into these compositions, to form steel?

MRS. B.

Not an atom: they are, therefore, very improperly called steel; but it is the vulgar appellation, and medical men themselves often comply with the general custom.

Sulphate of iron may be prepared, as you have seen, by dissolving iron in sulphuric acid; but it is generally obtained from the natural production called *pyrites*, which, being a sulphuret of iron, requires only exposure to the atmosphere to be

oxidated, in order to form the salt: this, therefore, is much the most easy way of procuring it on a large scale.

EMILY.

I am surprised to find that both acids and compound salts are generally obtained from their various combinations, rather than from the immediate union of their ingredients, which seems so much more simple.

MRS. B.


Were the simple bodies always at hand, their combinations would naturally be the most convenient method of forming compounds; but you must consider that, in general, there is great difficulty and expense in obtaining the simple ingredients from their combinations; it is, therefore, often more expedient to procure compounds from the decomposition of other compounds. But, to return to the sulphate of iron. — There is a certain vegetable acid called *gallic acid*, which has the remarkable property of precipitating this salt black. — I shall pour a few drops of the gallic acid into this solution of sulphate of iron —

CAROLINE.

It is become as black as ink!

MRS. B.

And it is ink in reality. Common writing ink is a precipitate of sulphate of iron by gallic acid; the black colour is owing to the formation of gallat



of iron, which, being insoluble, remains suspended in the fluid.

This acid has also the property of altering the colour of iron in its metallic state. You may frequently see its effect on the blade of a knife that has been used to cut certain kinds of fruits.

CAROLINE.

True; and that is, perhaps, the reason that a silver knife is preferred to cut fruit; the gallic acid, I suppose, does not act upon silver.—Is this acid found in all fruits?

MRS. B.

It is contained, more or less, in the rind of most fruits and roots, especially the radish, which, if scraped with a steel or iron knife, has its bright red colour changed to a deep purple, the knife being at the same time blackened. But the vegetable substance in which the gallic acid most abounds is *nutgall*, a kind of excrescence that grows on oaks, and from which the acid is commonly obtained for its various purposes.

We now come to the PHOSPHORIC and PHOSPHOROUS ACIDS. In treating of phosphorus, you have seen how these acids may be obtained from it by combustion.

EMILY.

Yes; but I should be much surprised if it was the usual method of obtaining them, since it is so very difficult to procure phosphorus in its pure state.

MRS. B.

You are right, my dear; the phosphoric acid, for general purposes, is extracted from bones, in which it is contained in the state of phosphate of lime: from this salt the phosphoric acid is separated by means of the sulphuric, which combines with the lime. In its pure state, phosphoric acid is either liquid or solid, according to its degree of concentration.

Among the salts formed by this acid, *phosphate of lime* is the only one which affords much interest; and this, we have already observed, constitutes the basis of all bones. It is also found in very small quantities in some vegetables.

CONVERSATION XVII.

OF THE NITRIC AND CARBONIC ACIDS; OR THE COMBINATIONS OF OXYGEN WITH NITROGEN AND CARBON; AND OF THE NITRATES AND CARBONATES.

MRS. B.

I AM almost afraid of introducing the subject of the NITRIC ACID, as I am sure that I shall be blamed by Caroline for not having made her acquainted with it before.

CAROLINE.

Why so, Mrs. B.?

MRS. B.

Because you have long known its radical, which is nitrogen or azote; and in treating of that element, I did not even hint that it was the basis of an acid.

CAROLINE.

And what could be your reason for not mentioning this acid sooner?

MRS. B.

I do not know whether you will think the reason sufficiently good to acquit me; but the omission, I assure you, did not proceed from negligence.

You may recollect that nitrogen was one of the first simple bodies which we examined: you were then ignorant of the theory of combustion, which I believe was, for the first time, mentioned in that lesson; and therefore it would have been in vain, at that time, to have attempted to explain the nature and formation of acids.

CAROLINE.

I wonder, however, that it never occurred to us to inquire whether nitrogen could be acidified; for, as we know it was classed among the combustible bodies, it was natural to suppose that it might produce an acid.

MRS. B.

That is not a necessary consequence: for it might combine with oxygen only in the degree requisite to form an oxide. But you will find that nitrogen is susceptible of various degrees of oxygenation, some of which convert it merely into an oxide, and others give it all the acid properties.

The acids resulting from the combination of oxygen and nitrogen are called the NITROUS and NITRIC acids. We will begin with the NITRIC, in which nitrogen is in the highest state of oxygenation. The acid has so powerful an attraction for water that it has never been obtained perfectly free from it. But water may be so strongly impregnated with it as to form an exceedingly powerful acid solution. Here is a bottle of this acid, which, you see, is quite limpid.

CAROLINE.

What a strong offensive smell it has !

MRS. B.

This acid contains a greater abundance of oxygen than any other ; but it retains it with very little force.

EMILY.

Then it must be a powerful caustic, both from the facility with which it parts with its oxygen, and the quantity which it affords.

MRS. B.

Very well, Emily ; both cause and effect are exactly such as you describe ; nitric acid burns and destroys all kinds of organised matter. It even sets fire to some of the most combustible substances. — We shall pour a little of it over this piece of dry warm charcoal—you see it inflames it immediately ; it would do the same with oil of turpentine, phosphorus, and several other very combustible bodies. This shows you how easily this acid is decomposed by combustible bodies, since these effects must depend upon the absorption of its oxygen.

Nitric acid has been used in the arts from time immemorial : but it is only within the last fifty years that its chemical nature has been ascertained. The celebrated Mr. Cavendish discovered that it consisted of about 10 parts of nitrogen and 25 of oxygen.* These principles, in their gaseous state,

* The proportion stated by Sir H. Davy, in his Chemical Researches, is as 1 to 2·389.

combine at a high temperature: and this may be effected by repeatedly passing the electrical spark through a mixture of the two gases.

EMILY.

The nitrogen and oxygen gases, of which the atmosphere is composed, do not combine, I suppose, because their temperature is not sufficiently elevated.

CAROLINE.

But in a thunder-storm, when the lightning repeatedly passes through them, may it not produce nitric acid? We should be in a strange situation, if a violent storm should at once convert the atmosphere into nitric acid.

MRS. B.

There is no danger of it, my dear; the lightning can affect but a very small portion of the atmosphere; and though it were occasionally to produce a little nitric acid, it never could happen to such an extent as to be perceptible.

EMILY.

But how could the nitric acid be known, and used, before the method of combining its constituents was discovered?

MRS. B.

Previous to that period the nitric acid was obtained, and it is, indeed, still extracted, for the common purposes of art, from the compound salt which it forms from potash, commonly called *nitre*.

CAROLINE.

Why is it so called? Pray, Mrs. B., let these old unmeaning names be entirely given up, by us at least; and let us call this salt *nitrate of potash*.

MRS. B.

With all my heart; but it is necessary that I should, at least, mention the old names, and more especially those which are yet in common use; otherwise, when you meet with them, you would not be able to understand their meaning.

EMILY.

And how is the acid obtained from this salt?

MRS. B.

By the intervention of sulphuric acid, which combines with the potash, and sets the nitric acid at liberty. This I can easily show you, by mixing some nitrate of potash and sulphuric acid in this retort, and heating it over a lamp; the nitric acid will come over in the form of vapour, which we shall collect in a glass bell. This acid, diluted in water, is commonly called *aqua fortis*,—if Caroline will allow me to mention that name.

CAROLINE.

I have often heard that *aqua fortis* will dissolve almost all metals: it is no doubt because it yields its oxygen so easily.

MRS. B.

Yes; and from this powerful solvent property it derived the name of *aqua fortis*, or strong water.

Do you not recollect that we oxidated, and afterwards dissolved, some copper in this acid ?

EMILY.

If I remember right, the nitrate of copper was the first instance you gave us of a compound salt. Can nitric acid be completely decomposed and converted into nitrogen and oxygen ?

CAROLINE.

That cannot be the case, Emily ; since the acid can be decomposed only by the combination of its constituents with other bodies.

MRS. B.

True ; but caloric is sufficient for this purpose. By making the acid pass through a red-hot porcelain tube it is decomposed ; the nitrogen and oxygen regain the caloric which they had lost in combining, and are thus both restored to their gaseous state.

The nitric acid may also be partly decomposed, and is by this means converted into NITROUS ACID.

CAROLINE.

This conversion must be easily effected, as the oxygen is so slightly combined with the nitrogen.

MRS. B.

The partial decomposition of nitric acid is readily effected by most metals ; but it is sufficient to expose the nitric acid to a very strong light to make it give out oxygen gas, and thus be con-

verted into nitrous acid. This latter acid appears in various degrees of strength, according to the proportions of nitrous acid gas and water, of which it is composed: the strongest is of a yellow colour, as you see in this bottle.

CAROLINE.

How it fumes when the stopper is taken out!

MRS. B.

The acid exists naturally in a gaseous state, and is here so strongly concentrated in water, that it is constantly escaping.

Here is another bottle of nitrous acid, which, you see, is of an orange-red: this acid is weaker, that is, contains a smaller quantity of the acid gas; and with a still less proportion of the gas it is of an olive-green colour, as it appears in this third bottle. In short, the weaker the acid, the deeper is its colour.

Nitrous acid acts still more powerfully on some inflammable substances than the nitric.

EMILY.

I am surprised at that, as it contains less oxygen.

MRS. B.

But, on the other hand, it parts with it much more readily: you may recollect that we once inflamed oil with this acid.

The next combinations of nitrogen and oxygen form only oxides of nitrogen, the first of which is commonly called *nitrous air*; or, more properly,

nitric oxide gas. This may be obtained from nitric acid, by exposing the latter to the action of metals, as in dissolving them it does not yield the whole of its oxygen, but retains a portion of this principle sufficient to convert it into this peculiar gas, a specimen of which I have prepared, and preserved within this inverted glass bell.

EMILY.

It is a perfectly invisible elastic fluid.

MRS. B.

Yes; and it may be kept any length of time in this manner over water, as it is not, like the nitric and nitrous acids, absorbable by it. It is rather heavier than atmospherical air, and is incapable of supporting either combustion or respiration. I am going to incline the glass gently on one side, so as to let some of the gas escape.

EMILY.

How very curious!—It produces orange fumes like the nitrous acid; which is the more extraordinary, as the gas within the glass is perfectly invisible.

MRS. B.

It would give me much pleasure if you could make out the reason of this curious change without requiring any further explanation.

CAROLINE.

It seems, by the colour and smell, as if it were converted into nitrous acid gas; yet that cannot

be, unless it combines with more oxygen: and how can it obtain oxygen the very instant it escapes from the glass?

EMILY.

From the atmosphere, no doubt. Is it not so, Mrs. B.?

MRS. B.

You have guessed it: as soon as it comes in contact with the atmosphere, it absorbs from it the additional quantity of oxygen requisite to convert it into nitrous acid gas. And if I now remove the bottle entirely from the water, so as to bring at once the whole of the gas into contact with the atmosphere, this conversion will appear still more striking.

EMILY.

Look, Caroline; the whole capacity of the bottle is instantly tinged with an orange colour!

MRS. B.

Thus, you see, it is the most easy process imaginable to convert *nitrous oxide gas* into *nitrous acid gas*. The property of attracting oxygen from the atmosphere, without any elevation of temperature, has occasioned this gaseous oxide to be used as a test for ascertaining the degree of purity of the atmosphere. I am going to show you how this is done. — You see this graduated glass tube, which is closed at one end (Plate XIII. fig. 2.) — I first fill it with water, and then introduce a certain measure of nitrous gas, which, not being ab-

sorbable by water, passes through it, and occupies the upper part of the tube. I now add rather above two thirds of oxygen gas, which will just be sufficient to convert the nitrous oxide gas into nitrous acid gas.

CAROLINE.

So it has!—I saw it turn to an orange colour; but it immediately afterwards disappeared entirely, and the water, you see, has risen, and almost filled the tube.

MRS. B.

That is because the acid gas is absorbable by water; and in proportion as the gas impregnates the water, the latter rises in the tube. When the oxygen gas is very pure, and the required proportion of nitrous oxide gas very exact, the whole is absorbed by the water; but if any other gas be mixed with the oxygen, instead of combining with the nitrous oxygen, it will remain, and occupy the upper part of the tube; or if the gases be not in the due proportion, there will be a residue of that which predominates. — Before we leave this subject, I must not forget to remark, that nitrous acid may be formed by dissolving nitrous oxide gas in nitric acid. This solution may be effected simply by making bubbles of nitrous oxide gas pass through nitric acid.

EMILY.

That is to say, that nitrogen at its highest degree of oxygenation, being mixed with nitrogen at its

lowest degree of oxygenation, will produce an intermediate substance, which is nitrous acid.

MRS. B.

You have stated the fact with great precision. — There are various other methods of preparing nitrous oxide, and of obtaining it from compound bodies; but it is not necessary to enter into these particulars. It remains for me only to mention another curious modification of oxygenated nitrogen, which has been distinguished by the name of *gaseous oxide of nitrogen*. This gas has been accurately examined, and its properties investigated, chiefly by Sir H. Davy. It has obtained also the name of *exhilarating gas*, from the very singular property which he discovered in it, of raising the animal spirits, when inhaled into the lungs, to a degree sometimes resembling delirium or intoxication.

CAROLINE.

Is it respirable, then?

MRS. B.

It can scarcely be called respirable, as it would not support life for any length of time; but it may be breathed for a few moments without any other effects than the singular exhilaration of spirits I have just mentioned. It affects people, however, in various manners: some become violent, even outrageous; others experience a languor, attended with faintness; but most agree in opinion that the sensations it excites are extremely pleasant.

CAROLINE.

I think I should like to try it. How do you breathe it?

MRS. B.

By collecting the gas in a bladder, to which a short tube with a stopcock is adapted; that is applied to the mouth with one hand, whilst the nostrils are kept closed with the other, in order that the common air may have no access. You then alternately inspire and expire the gas, till you perceive its effects. But I cannot consent to your making the experiment; for the nerves are sometimes unpleasantly affected by it, and I would not run any risk of that kind.

EMILY.

I should like, at least, to see somebody breathe it; but pray, by what means is this curious gas obtained?

MRS. B.

It is procured from *nitrate of ammonia*, an artificial salt, which yields it on the application of a gentle heat. I have put some of the salt into a retort, and by the aid of a lamp the gas will be extricated.

CAROLINE.

Bubbles of air begin to escape through the neck of the retort into the water apparatus; will you not collect them?

MRS. B.

The gas that first comes over need not be pre-

served, as it consists of little more than the common air that was in the retort; besides, there is always in this experiment a quantity of watery vapour, which must come away before the nitrous oxide appears.

EMILY.

Watery vapour! Whence does that proceed? There is no water in nitrate of ammonia?

MRS. B.

You must recollect that there is in every salt a quantity of water of crystallisation, which may be evaporated by heat alone. But, besides this, water is actually generated in this experiment, as you will see presently. First tell me, what are the constituent parts of nitrate of ammonia?

EMILY.

Ammonia and nitric acid: this salt, therefore, contains three different elements; nitrogen and hydrogen, which produce the ammonia; and oxygen, which, with nitrogen, forms the acid.

MRS. B.

Well, then, in this process the ammonia is decomposed; the hydrogen quits the nitrogen to combine with some of the oxygen of the nitric acid, and forms with it the watery vapour which is now coming over. When that is effected, what will you expect to find?

114 OF THE NITRIC AND NITROUS ACIDS.

EMILY.

Nitrous acid instead of nitric acid, and nitrogen instead of ammonia.

MRS. B.

Exactly so; and the nitrous acid and nitrogen combine and form the gaseous oxide of nitrogen, in which the proportion of oxygen is 37 parts to 63 of nitrogen.

You may have observed that for a little while no bubbles of air have come over, and we have perceived only a stream of vapour condensing as it issued into the water. — Now bubbles of air again make their appearance, and I imagine that by this time all the watery vapour is come away, and that we may begin to collect the gas. We may try whether it is pure by filling a phial with it, and plunging a taper into it. — Yes, it will do now, for the taper burns brighter than in the common air, and with a greenish flame.

CAROLINE.

But how is that? I thought no gas would support combustion but oxygen or chlorine.

MRS. B.

Or any gas that contains oxygen, and is ready to yield it, which is the case with this in a considerable degree; it is not, therefore, surprising that it should accelerate the combustion of the taper.

You see that the gas is now produced in great

abundance; we shall collect a large quantity of it, and I dare say that we shall find some of the family who will be curious to make the experiment of respiring it. Whilst this process is going on, we may take a general survey of the most important combinations of the nitric and nitrous acids with the alkalies.

The first of these is *nitrate of potash*, commonly called *nitre* or *saltpetre*.

CAROLINE.

Is not that the salt with which gunpowder is made?

MRS. B.

Yes. Gunpowder is a mixture of five parts of nitre to one of sulphur and one of charcoal. — Nitre, from its great proportion of oxygen, and from the facility with which it yields it, is the basis of most detonating compositions.

EMILY.

But what is the cause of the violent detonation of gunpowder when set fire to?

MRS. B.

Detonation may proceed from two causes: the sudden formation, or destruction, of an elastic fluid. In the first case, when either a solid or liquid is instantaneously converted into an elastic fluid, the prodigious and sudden expansion of the body strikes the air with great violence, and this concussion produces the sound called detonation.

CAROLINE.

That I understand very well. But how can a similar effect be produced by the destruction of a gas?

MRS. B.

A gas can be destroyed only by condensing it to a liquid or solid state: when this takes place suddenly, the gas, in assuming a new and more compact form, produces a vacuum, into which the surrounding air rushes with great impetuosity; and it is by that rapid and violent motion that the sound is produced. In all detonations, therefore, gases are either suddenly formed, or destroyed. In that of gunpowder, can you tell me which of these two circumstances takes place?

EMILY.

As gunpowder is a solid, it must, of course, produce the gases in its detonation; but how, I cannot tell.

MRS. B.

The constituents of gunpowder, when heated to a certain degree, enter into a number of new combinations, and are instantaneously converted into a variety of gases, the sudden expansion of which gives rise to the detonation.

CAROLINE.

And in what instance does the destruction or condensation of gases produce detonation?

MRS. B.

I can give you one with which you are well acquainted; the sudden combination of the oxygen and hydrogen gases.

CAROLINE.

True; I recollect perfectly that hydrogen detonates with oxygen when the two gases are converted into water.

MRS. B.

Now let us return to the nitrate of potash.—This salt is decomposed when exposed to heat, and mixed with any combustible body, such as carbon, sulphur, or metals, these substances oxidating rapidly at the expense of the nitrate. I must show you an instance of this.—I expose to the fire some of the salt in a small iron ladle, and, when it is sufficiently heated, add to it some powdered charcoal: this will attract the oxygen from the salt, and be converted into carbonic acid.

EMILY.

But what occasions that crackling noise, and those vivid flashes that accompany it?

MRS. B.

The rapidity with which the carbonic acid gas is formed occasions a succession of small detonations, which, together with the emission of flame, is called *deflagration*.

Nitrate of ammonia we have already noticed, on

account of the gaseous oxide of nitrogen which is obtained from it.

Nitrate of silver is the lunar caustic, so remarkable for its property of destroying animal fibre; for which purpose it is often used by surgeons. — We have said so much, on a former occasion, on the mode in which caustics act on animal matter, that I shall not detain you any longer on this subject.

We now come to the CARBONIC ACID, which we have already had many opportunities of noticing. It is naturally of a gaseous form, but may be condensed into a liquid, and even become solid, by the action of strong pressure and intense cold. You recollect that this acid may be formed by the combustion of carbon, whether in its imperfect state of charcoal, or in its purest form of diamond. And it is not necessary, for this purpose, to burn the carbon in oxygen gas, as we did in the preceding lecture; for you need only light a piece of charcoal and suspend it under a receiver on the water bath. The charcoal will soon be extinguished, and the air in the receiver will be found mixed with carbonic acid. The process, however, is much more expeditious if the combustion be performed in pure oxygen gas.

CAROLINE.

But how can you separate the carbonic acid, obtained in this manner, from the air with which it is mixed?

MRS. B.

The readiest mode is to introduce under the receiver a quantity of caustic lime, or caustic alkali, which soon attracts the whole of the carbonic acid to form a carbonate. — The alkali is found increased in weight, and the volume of the air is diminished by a quantity equal to that of the carbonic acid which was mixed with it.

EMILY.

Pray, is there no method of obtaining pure carbon from carbonic acid?

MRS. B.

For a long time it was supposed that carbonic acid was not decomposable; but Mr. Tennant discovered that this acid may be decomposed by burning phosphorus in a closed vessel with carbonate of soda or carbonate of lime; the phosphorus absorbs the oxygen from the carbonate, whilst the carbon is separated in the form of a black powder. This decomposition, however, is not effected simply by the attraction of the phosphorus for oxygen, since it is weaker than that of charcoal; but the attraction of the alkali or lime for the phosphoric acid unites its power at the same time.

CAROLINE.

Cannot we make that experiment?

MRS. B.

Not easily; it requires being performed with

extreme nicety, in order to obtain any sensible quantity of carbon, and the experiment is much too delicate for me to attempt. There can, however, be no doubt of the accuracy of the results; which are, that carbonic acid gas consists of about twenty-eight parts of carbon to seventy-two of oxygen gas. But if you recollect, we decomposed carbonic acid gas the other day by burning potassium in it.

CAROLINE.

True, so we did; and found the carbon precipitated on the regenerated potash.

MRS. B.

Carbonic acid gas is found very abundantly in nature; it is supposed to form about one thousandth part of the atmosphere, and is constantly produced by the respiration of animals; it exists in a great variety of combinations, and is exhaled from many natural decompositions. It is contained in a state of great purity in certain caves, such as the *Grotto del Cane*, near Naples.

EMILY.

I recollect having read an account of that grotto, and of the cruel experiments made on the poor dogs, to gratify the curiosity of strangers. But I thought that the vapour exhaled by this cave was *fixed air*.

MRS. B.

That is the name by which carbonic acid was

known before its chemical composition was discovered. — This gas is more destructive of life than any other; and if the poor animals that are submitted to its effects are not plunged into cold water as soon as they become senseless, they do not recover. It extinguishes flame instantaneously. I have collected some in this glass, which I will pour over the candle.

CAROLINE.

This is extremely singular — as the gas is invisible, it seems to extinguish the light as it were by enchantment. I never should have imagined that gas could have been poured like a liquid.

MRS. B.

It can be done with carbonic acid only, as no other gas is sufficiently heavy to be susceptible of being poured out in the atmospherical air without mixing with it.

EMILY.

Pray, by what means did you obtain this gas?

MRS. B.

I procured it from marble. Carbonic acid gas has so strong an attraction for all the alkalis and alkaline earths, that these are always found in nature in the state of carbonates. Combined with lime, this acid forms chalk, which may be considered as the basis of all kinds of marbles and calcareous stones. From these substances carbonic acid is easily separated, as it adheres so slightly to

its combinations, that the carbonates are all decomposable by any of the other acids. I can easily show you how I obtained this gas; I poured some diluted sulphuric acid over pulverised marble in this bottle (the same which we used the other day to prepare hydrogen gas), and the gas escaped through the tube connected with it: the operation still continues, as you may perceive.

EMILY.

Yes, it does; there is a great fermentation in the glass vessel. What singular commotion is excited by the sulphuric acid taking possession of the lime, and driving out the carbonic acid! But did the carbonic acid exist in a gaseous state in the marble?

MRS. B.

Certainly not; the acid is capable of existing in a solid form, especially when combined with other bodies.

EMILY.

Whence, then, does it obtain the caloric necessary to convert it into gas?

MRS. B.

It may be supplied in this case from the mixture of sulphuric acid and water, which produces an evolution of heat, even greater than is required for the purpose; since, as you may perceive by touching the glass vessel, a considerable quantity of the caloric disengaged becomes sensible. But a supply of caloric may be obtained also from a

diminution of capacity for heat, occasioned by the new combination which takes place; and, indeed, this must be the case when other acids are employed for the disengagement of carbonic acid gas, which do not, like the sulphuric, produce heat on being mixed with water. Carbonic acid may likewise be freed from its combinations by heat alone, which restores it to its gaseous state.

CAROLINE.

It appears to me very extraordinary that the same gas which is produced by the burning of wood and coals should exist also in such bodies as marble and chalk, which are incombustible substances!

MRS. B.

I will not answer that objection, Caroline, because I think I can put you in a way of doing it yourself. Is carbonic acid combustible?

CAROLINE.

Why, no — because it is a body which has been already burnt; it is carbon only, and not the acid, that is combustible.

MRS. B.

Well, and what inference do you draw from this?

CAROLINE.

That carbonic acid cannot render the bodies with which it is united combustible; but that simple carbon does; and that it is in this element-

ary state that it exists in wood, coals, and a great variety of other combustible bodies. — Indeed, Mrs. B. you are very ungenerous; you are not satisfied with convincing me that my objections are frivolous, but you oblige me to prove them so myself.

MRS. B.

You must confess, however, that I make ample amends for the detection of error by enabling you to discover the truth. You understand now, I hope, that carbonic acid is equally produced by the decomposition of chalk, or by the combustion of charcoal. These processes are certainly of a very different nature: in the first case the acid is already formed, and requires nothing more than heat to restore it to its gaseous state; whilst, in the latter, the acid is actually made by the process of combustion.

CAROLINE.

I understand it now perfectly. But I have just been thinking of another difficulty, which, I hope, you will excuse my not being able to remove myself. How does the immense quantity of calcareous earth, which is spread all over the globe, obtain the carbonic acid with which it is combined?

MRS. B.

The question is, indeed, not very easy to answer; but I conceive that the general carbonisation of calcareous matter may have been the effect of a

general combustion, occasioned by some revolution of our globe, and producing an immense supply of carbonic acid, with which the calcareous matter became impregnated, or that it may have been effected gradually by the absorption of carbonic acid from the atmosphere. — But this would lead us to discussions in which we cannot indulge without deviating too much from our subject.

EMILY.

How does it happen that we do not perceive the pernicious effects of the carbonic acid which is floating in the atmosphere?

MRS. B.

On account of the state of very great dilution in which it exists there. But can you tell me, Emily, what are the sources which keep the atmosphere constantly supplied with this acid?

EMILY.

I suppose the combustion of wood, coals, and other substances that contain carbon.

MRS. B.

And also the breath of animals.

CAROLINE.

The breath of animals! I thought you said that this gas was not at all respirable, but, on the contrary, extremely poisonous.

MRS. B.

So it is; but although animals cannot breathe

in carbonic acid gas, yet, in the process of respiration, they have the power of forming this gas in their lungs; so that the air which we *expire*, or reject from the lungs, always contains a certain proportion of carbonic acid, which is much greater than that which is commonly found in the atmosphere.

CAROLINE.

But what is it that renders carbonic acid such a deadly poison?

MRS. B.

The manner in which this gas destroys life seems to be merely by preventing the access of respirable air; for carbonic acid gas, unless very much diluted with common air, does not penetrate into the lungs, as the windpipe actually contracts, and refuses it admittance. — But we must dismiss this subject at present, as we shall have an opportunity of treating of respiration much more fully when we come to the chemical functions of animals.

EMILY.

Is carbonic acid as destructive to the life of vegetables as it is to that of animals?

MRS. B.

If a vegetable be completely immersed in it, I believe it generally proves fatal to it; but mixed in certain proportions with atmospherical air, it is, on the contrary, very favourable to vegetation.

You remember, I suppose, our mentioning the

mineral waters, both natural and artificial, which contain carbonic acid gas?

CAROLINE.

You mean the Seltzer water?

MRS. B.

That is one of those which are the most used; there are, however, a variety of others into which carbonic acid enters as an ingredient; all these waters are usually distinguished by the name of *acidulous* or *gaseous mineral waters*.

The class of salts called *carbonates* is the most numerous in nature: we must pass over them in a very cursory manner, as the subject is far too extensive for us to enter on it in detail. The state of carbonate is the natural state of a vast number of minerals, and particularly of the alkalies and alkaline earths. They have so great an attraction for the carbonic acid, that they are almost always found combined with it; and you may recollect, that it is only by separating them from this acid, that they acquire that causticity and those striking qualities which I have formerly described. All marbles, chalks, shells, calcareous spars, and limestones of every description, are neutral salts, in which *lime*, their common basis, has lost all its characteristic properties.

EMILY.

But if all these various substances are formed

by the union of lime with carbonic acid, whence arises their diversity of form and appearance?

MRS. B.

Both from the different proportions of their component parts, and from a variety of foreign ingredients which may be occasionally blended with them: the veins and colours of marbles, for instance, proceed from a mixture of metallic substances; silex and alumine, also, frequently enter into these combinations. The various carbonates, therefore, which I have enumerated, cannot be considered as pure unadulterated neutral salts, although they certainly belong to that class of bodies.

CONVERSATION XVIII.

ON THE BORACIC, FLUORIC, AND MURIATIC ACIDS ; ON
CHLORINE ; AND ON MURIATES. — ON IODINE AND
IODIC ACID.

MRS. B.

WE now come to the three remaining acids with simple bases, the compound nature of which, though long suspected, has since been proved. The chief of these is the muriatic ; but I shall first describe the two others, as their bases have been obtained more distinctly than that of the muriatic acid.

You may recollect I mentioned the BORACIC ACID. This is found very sparingly in some parts of Europe, but for the use of manufacturers we have always received it from the remote country of Thibet, where it is found in some lakes combined with soda. It is easily separated from the soda by sulphuric acid, and appears in the form of shining scales, as you see here.

CAROLINE.

I am glad to meet with an acid which we need not be afraid to touch ; for I perceive, from your

keeping it in a piece of paper, that it is more innocent than our late acquaintances, the sulphuric and nitric acids. .

MRS. B.

Certainly; but being also more inert, you will not find its properties so interesting. However, its decomposition, and the brilliant spectacle it affords when its basis again unites with oxygen, atones for its want of other striking qualities.

Sir H. Davy decomposed this acid by various methods. On exposing it to the Voltaic battery, the positive wire gave out oxygen, and on the negative wire a black substance was deposited. This was the basis of the acid, which Sir H. Davy called *Boracium* or *Boron*.

The same substance was obtained in more considerable quantities by exposing the acid to a great heat in an iron gun-barrel.

A third method of decomposing the boracic acid consisted in burning potassium in contact with it *in vacuo*. The potassium attracts the oxygen from the acid, and leaves its basis in a separate state.

The recomposition of this acid I shall show you, by burning some of its basis, which you see here, in a retort full of oxygen gas. The heat of a candle is all that is required for this combustion.

EMILY.

The light is astonishingly brilliant, — and what beautiful sparks it throws out!

MRS. B.

The result of this combustion is the boracic acid, the nature of which, you see, is proved both by analytic and synthetic means. Its basis has not, it is true, a metallic appearance; but it makes very hard alloys with other metals.

EMILY.

But pray, Mrs. B., for what purpose is the boracic acid used in manufactures?

MRS. B.

Its principal use is in conjunction with soda, that is, in the state of *borate of soda*, which in the arts is commonly called borax. This salt has a peculiar power of dissolving metallic oxides, and of promoting the fusion of substances capable of being melted: it is accordingly employed in various metallic arts; it is used, for example, to remove the oxide from the surface of metals, and is often employed in the assaying of metallic ores.

Let us now proceed to the FLUORIC ACID. This acid is obtained from a substance which is found frequently in mines, and particularly in those of Derbyshire, called *fluor*, a name which it acquired from the circumstance of its being used to render the ores of metals more fluid when heated.

CAROLINE.

Pray is not this the Derbyshire spar, of which so many ornaments are made?

MRS. B.

The same; but, though it has long been employed for a variety of purposes, its nature was unknown until Scheele, the great Swedish chemist, discovered that it consisted of lime united with a peculiar acid, which obtained the name of *fluoric acid*. It is easily separated from the lime by the sulphuric acid, and, unless condensed in water, ascends in the form of gas. A very peculiar property of this acid is its union with siliceous earths, which I have already mentioned. If the distillation of this acid is performed in glass vessels, they are corroded, and the siliceous part of the glass comes over, united with the gas; if water be then admitted, part of the silica will be deposited, as you may observe in this jar.

CAROLINE.

I see white flakes forming on the surface of the water: is that silica?

MRS. B.

Yes, it is. This power of corroding glass has been used for engraving, or rather etching, upon it. The glass is first covered with a coat of wax, through which the figures to be engraved are to be scratched with a pin; then, pouring the fluoric acid over the wax, it corrodes the glass where the scratches have been made.

CAROLINE.

I should like to have a bottle of this acid to make engravings.

MRS. B.

But you could not have it in a *glass* bottle, for in that case the acid would be saturated with silica, and incapable of executing an engraving; the same thing would happen were the acid kept in vessels of porcelain or earthenware: this acid must therefore be both prepared and preserved in vessels of silver.

If it be distilled from fluor spar and sulphuric acid, in silver or leaden vessels, the receiver being kept very cold during the distillation, it assumes the form of a dense fluid, and in that state is the most intensely corrosive substance known. This seems to be the acid combined with a little water. It may be called *hydro-fluoric acid*; and Sir H. Davy was led, from some experiments on the subject, to consider *pure* fluoric acid as a compound of a certain unknown principle, which he called *fluorine*, with hydrogen.

Sir H. Davy also attempted to decompose the fluoric acid by burning potassium in contact with it; but he was not able, by this or any other method, to obtain its basis in a distinct separate state.

We shall conclude our account of the acids with that of the MURIATIC, or, as it is often now called, *Hydrochloric* ACID, which is, perhaps, the most curious and interesting of them all. It is found in nature combined with soda, lime, and

magnesia. *Muriate of soda* is the common sea-salt; and from this substance the acid is usually disengaged by means of the sulphuric acid. The natural state of the muriatic acid is that of an invisible permanent gas, at the common temperature of the atmosphere; but it has a remarkably strong attraction for water, and assumes the form of a whitish cloud whenever it meets any moisture to combine with. This acid is remarkable for its peculiar and very pungent smell, and possesses, in a powerful degree, most of the acid properties. Here is a bottle containing muriatic acid in a liquid state.

CAROLINE.

And how is it liquefied?

MRS. B.

By impregnating water with it; its strong attraction for water makes it very easy to obtain it in a liquid form. Now, if I open the phial, you may observe a kind of vapour rising from it, which is muriatic acid gas, of itself invisible, but made apparent by combining with the moisture of the atmosphere.

EMILY.

Have you any of the pure muriatic acid gas?

MRS. B.

This jar is full of it in its gaseous state. It is inverted over mercury instead of water, because, being absorbable by the smallest quantity

of water, this gas cannot be confined by it. I shall now raise the jar a little on one side, and suffer some of the gas to escape. You see that it immediately becomes visible in the form of a cloud.

EMILY.

It must be, no doubt, from its uniting with the moisture of the atmosphere that it is converted into this dewy vapour.

MRS. B.

Certainly ; and for the same reason, that is to say, its extreme eagerness to unite with water, this gas will cause snow to melt as rapidly as an intense fire.

This acid proved much more refractory, when Sir H. Davy attempted to decompose it, than the other two undecomposed acids. It is singular that potassium will burn in muriatic acid, and be converted into potash, without decomposing the acid, and the result of this combustion is a *muriate of potash* ; for the potash, as soon as it is regenerated, combines with the muriatic acid.

CAROLINE.

But how can the potash be regenerated, if the muriatic acid does not oxidate the potassium ?

MRS. B.

The potassium, in this process, obtains oxygen from the moisture with which the muriatic acid is

always combined, and, accordingly, hydrogen, resulting from the decomposition of the moisture, is invariably evolved.

Sir H. Davy obtained very curious results from burning potassium in a mixture of phosphorus and muriatic acid, and also of sulphur and muriatic acid; the latter detonates with great violence. All his experiments, however, failed in presenting to his view the basis of the muriatic acid, of which he was in search; and he was at length induced to form an opinion respecting the nature of this acid which I shall presently proceed to explain.

The celebrated chemist Scheele, while examining the action of muriatic acid on oxide of manganese, discovered that a peculiar gas was disengaged. The French chemists named it oxygenated or oxymuriatic acid gas, concluding that it was produced by a part of the oxygen of the oxide of manganese combining with the muriatic acid. This gas is easily procured for experimental purposes, by mixing in a retort one part of muriatic acid with two of oxide of manganese, and applying the heat of a lamp. The gas is soon disengaged, and may be received over warm water, as it is but sparingly absorbed by it. I have collected some in this jar.

EMILY.

It is not invisible, like the generality of gases, for it is of a yellowish colour.

MRS. B.

It is considerably heavier than atmospheric air, its specific gravity being about 2.5. It is even susceptible of being congealed, or solidified, by a certain degree of cold. Till within the last forty years, oxymuriatic acid was universally considered as a compound body; but in the year 1811, Sir H. Davy, after a minute investigation of the properties of this gas, proved, that, instead of being a compound of muriatic acid and oxygen, it was a *simple body*, having a great analogy with oxygen in most of its properties, being susceptible of combining with inflammable bodies, and also being capable of uniting in various proportions with oxygen itself. It became necessary, therefore, to change its name, and Sir H. Davy called it *chlorine*, from its greenish colour; and, in compliance with his theory, which has been long since universally adopted, we have placed it in the table of simple bodies under that name.

EMILY.

Do you mean to say that chlorine is, like oxygen, a supporter of combustion?

MRS. B.

In many cases it is so. I have here several glass jars containing chlorine; in the first we shall introduce some Dutch gold leaf. Do you observe that it takes fire?

EMILY.

It does, indeed: how wonderful this is! It became immediately red-hot; but was soon smothered in the thick vapour its combustion produced.

CAROLINE.

What a disagreeable smell!

MRS. B.

We shall try the same experiment with phosphorus, in another jar of the gas. You had better keep your handkerchief to your nose when I open the jar to introduce the phosphorus.

CAROLINE.

Look, Emily, it burns almost with the same brilliancy as in oxygen gas. But what appears to me most extraordinary is, that these combustions take place without the metal or the phosphorus being previously lighted, or even in the least heated.

MRS. B.

All these curious effects are owing to the very great facility with which chlorine enters into chemical combination with such substances as are strongly disposed to unite with it: and during that combination a considerable quantity of heat is disengaged, sufficient in many cases to inflame the substance.

EMILY.

Why did you burn Dutch gold leaf rather than any other metal?

MRS. B.

Because it is a composition of metals (consisting chiefly of copper) which burns readily; but several other metals, such as antimony and arsenic, exhibit the same phenomena in a less degree. I use a thin metallic leaf in preference to a lump of metal, because it offers to the action of the gas but a small quantity of matter under a large surface. Filings or shavings would answer the purpose nearly as well; but a lump of metal, though the surface would be acted upon with great rapidity, would not take fire. Pure gold is not inflamed by chlorine, but if exposed to it in the shape of a thin leaf, it becomes red hot, and is rapidly dissolved by it: indeed, this gas is the only one which will dissolve gold.

EMILY.

This then, I suppose, is what is commonly called *aqua regia*, which you know is the only thing that will act upon gold.

MRS. B.

That is not exactly the case either; for *aqua regia* is composed of a mixture of muriatic acid and nitric acid; but the result of this mixture is, in fact, the formation of chlorine, as you will hereafter understand; and it is by the action of the chlorine that the gold is dissolved.

Sulphur, volatile oils, and many other substances, will burn in the same manner in chlorine gas; but I have not prepared a sufficient quantity.

of it to show you the combustion of all these bodies.

CAROLINE.

You have not yet explained to us the composition of muriatic acid, to which you alluded a few minutes ago.

MRS. B.

True; I avoided noticing it then, because you could not have understood it without some previous knowledge of chlorine, which I had but just introduced to your acquaintance.

Sir H. Davy proved that muriatic acid, instead of being a compound consisting of an unknown basis and oxygen, is formed by the union of chlorine with hydrogen. It is on this account that it is now frequently designated by the name of *hydrochloric acid*, and its salt by that of *hydrochlorates*.

CAROLINE.

And what were the reasons which induced philosophers to adopt an opinion so contrary to that which had hitherto prevailed?

MRS. B.

There are many circumstances which induced them to do so; but the clearest and simplest fact in its support is, that if equal volumes of hydrogen and chlorine be mixed together, and exposed to the flame of a candle or the direct rays of the sun, an explosion takes place, both these gases disappear, and muriatic acid is formed.

EMILY.

That seems to afford a complete proof of the new theory. But, according to this theory, how can you explain the formation of chlorine from a mixture of muriatic acid and oxide of manganese?

MRS. B.

Very easily: the muriatic acid is decomposed, its hydrogen unites with the oxygen of the manganese to form water, and the chlorine appears in its separate state.

Although this new theory gained ground very rapidly, almost immediately after Sir H. Davy had published his views upon the subject, it was not considered as completely established until the discovery of iodine, and, more recently, of brome, both of which we shall presently notice.

Chlorine does not, like the acids, redden blue vegetable colours; but it totally destroys all colour, turning vegetables perfectly white. In order to see this effect, let us collect some vegetable colours to put into this glass jar, which is filled with gas.

EMILY.

Here is a sprig of myrtle, and a rose.

CAROLINE.

And here some turmeric paper, and some scarlet riband. Their colours begin to fade immediately on being introduced into the jars; but how does the gas produce this effect?

MRS. B.

It destroys the colouring matter by combining with the hydrogen which enters into its composition, and forming with it muriatic acid. Old prints may be cleaned by this acid, for the paper may be whitened without injury to the impression, printers' ink consisting of materials (oil and lamp-black) which are not acted upon by acids.

This property of chlorine has been employed in manufactures, in a variety of bleaching processes; but for these purposes the gas must be dissolved in water, as the acid is thus rendered much milder, and less powerful in its effects; for in a gaseous state it would destroy the texture as well as the colour of the substance submitted to its action.

CAROLINE.

Look at the things which we put into the jars; they have entirely lost their colour!

MRS. B.

The effect is completed; and, were we now to examine the gas we should find it to consist chiefly of muriatic acid. Chlorine has been used to purify the air in fever hospitals and prisons, as it burns and destroys putrid effluvia of every kind.

CAROLINE.

But I think the remedy must be nearly as bad as the disease, the smell of chlorine is so dreadfully suffocating.

MRS. B.

It is, certainly, extremely offensive; but by keeping the mouth shut, and wetting the nostrils with liquid ammonia, in order to neutralise the vapour as it reaches the nose, its deleterious effects may be in a great degree prevented. This mode of disinfection can, however, hardly be used in places which are inhabited; and as the vapour of nitric acid, which is scarcely less efficacious, is not at all prejudicial, it is usually preferred for such purposes.

The infection of the small-pox is also destroyed by this gas; and matter which has been submitted to its influence will no longer generate that disease.

Besides uniting with hydrogen and forming muriatic acid, chlorine combines also with oxygen in several proportions, forming two gaseous oxides, called *euchlorine* or *protoxide* of chlorine, and the *deutoxide* of chlorine; and also two acids containing considerably more oxygen, called *chloric* acid and *perchloric* acid. These acids can be made to combine with the earths and metals, forming *chlorates* and *perchlorates*.

We shall now proceed to the examination of the salts formed by muriatic, or, as it is now frequently called, *hydrochloric* acid. Among these, muriate of soda or common salt is the most interesting. According to the new theory, dry muriate of soda is a compound of chlorine and sodium; for it may be formed by the direct com-

bination of these substances. The uses and properties of this salt are too well known to require much comment ; besides the pleasant flavour which it imparts to food, it assists the process of digestion, and is very wholesome when not used to excess. Sea-water is the great source whence muriate of soda is obtained by evaporation ; but it is also found in large solid masses in the bowels of the earth, both in England and in many other parts of the world.

EMILY.

I thought that salts, when solid, were always in the state of crystals ; but the common table-salt is in the form of a coarse white powder.

MRS. B.

Crystallisation depends, as you may recollect, on the slow and regular reunion of particles dissolved in a fluid : common sea-salt is only in a state of imperfect crystallisation, because the process by which it is prepared is not favourable to the formation of regular crystals. But if you dissolve it, and afterwards evaporate the water slowly, you will obtain a regular crystallisation.

Muriate of ammonia is another combination of this acid, which we have already mentioned as the principal source from which ammonia is derived.

I can at once show you the formation of this salt, by the immediate combination of muriatic acid with ammonia. These two glass jars contain, the one muriatic acid gas, the other ammoniacal

gas, both of which are perfectly invisible ; now if I mix them together, you see they immediately form an opaque white cloud, like smoke. If a thermometer were placed in the jar in which these gases are mixed, you would perceive that some heat is at the same time produced.

EMILY.

The effects of chemical combinations are, indeed, wonderful ! How extraordinary it is that two invisible bodies should become visible by their union !

MRS. B.

This strikes you with astonishment, because it is a phenomenon which nature seldom exhibits to our view ; but the most common of her operations are as wonderful, and it is their frequency only that prevents our regarding them with equal admiration. What would be more surprising, for instance, than combustion, were it not rendered so familiar by custom ?

EMILY.

That is true ; but pray, Mrs. B., is this white cloud the salt that produces ammonia ? How different it is from the solid muriate of ammonia which you once showed us !

MRS. B.

It is the same substance, which first appears in the state of vapour, but will soon be condensed, by cooling against the sides of the jar, in the form of very minute crystals.

We may now proceed to examine the *chlorates*. In this class of salts, the *chlorate of potash* is the most worthy of our attention, from its striking properties. It is a compound of chloric acid, or chlorine and oxygen, with potash. If this salt be mixed and rubbed together with sulphur, phosphorus, charcoal, or, indeed, any other combustible, it explodes strongly.

CAROLINE.

It is, I suppose, like gunpowder, suddenly converted into elastic fluids.

MRS. B.

Yes; but with this difference, that no increase of temperature, any farther than that produced by gentle friction, is required in this instance. Can you discover what gases are generated by the detonation of this salt with charcoal?

EMILY.

Let me consider: the chloric acid of the chlorate of potash parts with its excess of oxygen to the charcoal, by which means it is converted into chlorine; while the charcoal, being burnt by the oxygen, is changed into carbonic acid gas. What becomes of the potash I cannot tell.

MRS. B.

It is a fixed product, which remains in the vessel.

I mean to show you this experiment; but I advise you not to attempt to repeat it alone; for unless great care be taken to mix only very small

quantities, the detonation will be extremely violent, and may be attended with dangerous effects. You see I mix a few particles only of the salt with a little powdered charcoal in this Wedgwood mortar, and rub them together with the pestle.

CAROLINE.

How can such a loud explosion be produced by so small a quantity of matter?

MRS. B.

You must consider that an extremely small quantity of solid substance may produce a very great volume of gases; and it is the sudden evolution of these which occasions the sound.

EMILY.

Would not chlorate of potash make stronger gunpowder than nitrate of potash?

MRS. B.

Yes; but the preparation, as well as the use of this salt, is attended with so much danger that it is never employed for that purpose.

CAROLINE.

There is no cause to regret it, I think; for the common gunpowder is quite sufficiently destructive.

MRS. B.

I can show you a very curious experiment with this salt; but it must again be on condition that you will never attempt to repeat it by yourselves. I throw a small piece of phosphorus into this

glass of water, then a little chlorate of potash, and, lastly, I pour in (by means of this funnel, so as to bring it in contact with the two other ingredients at the bottom of the glass,) a small quantity of sulphuric acid.

CAROLINE.

This is, indeed, a beautiful experiment! The phosphorus takes fire and burns from the bottom of the water.

EMILY.

How wonderful it is to see flame bursting out under water, and rising through it! Pray, how is this accounted for?

MRS. B.

Cannot you find it out, Caroline?

EMILY.

Stop — I think I can explain it. Is it not because the sulphuric acid decomposes the salt, by combining with the potash, so as to liberate the chlorine and oxygen, by which the phosphorus is set on fire?

MRS. B.

Very well, Emily; and with a little more reflection you would have discovered another concurring circumstance, which is, that an increase of temperature is produced by the mixture of the sulphuric acid and water, which assists in promoting the combustion of the phosphorus.

I must, before we part, introduce to your ac-

quaintance a more recently discovered substance, IODINE, which, you may recollect, we placed next to oxygen and chlorine in our table of simple bodies.

CAROLINE.

Is this also a body capable of maintaining combustion, like oxygen and chlorine?

MRS. B.

It is; and although it does not so generally disengage light and heat from inflammable bodies as oxygen and chlorine do, yet it will combine with most of them; and sometimes, as in the instance of potassium and phosphorus, the combination is attended with an actual appearance of light and heat.

CAROLINE.

But what sort of a substance is iodine? what is its form and colour?

MRS. B.

It is a very singular body, in many respects. At the ordinary temperature of the atmosphere, it commonly appears in the form of bluish-black crystalline scales, such as you see in this tube.

CAROLINE.

They shine like black lead, and some of the scales have the shape of lozenges.

MRS. B.

That is actually the form which the crystals of iodine often assume. But if we heat the tube

gently, by holding it over the flame of a candle, see what a change takes place in the crystals.

CAROLINE.

How curious! They seem to melt, and be transformed into a beautiful violet vapour. But look, Mrs. B., the same scales are now appearing at the other end of the tube.

MRS. B.

This is, in fact, a sublimation of iodine, from one part of the tube to another; but with this remarkable peculiarity, that, while in the gaseous state, iodine assumes that bright violet colour, which, as you may already perceive, it loses as the tube cools, and the substance resumes its usual solid form. It is from the violet colour of the gas that iodine has obtained its name.

CAROLINE.

But how is this curious substance obtained?

MRS. B.

It is found in the ley of ashes of sea-weeds, after the soda has been separated by crystallisation; and it is disengaged by means of sulphuric acid, which expels it from the alkaline ley in the form of a violet gas, which may be collected and condensed in the way you have just seen. This curious substance was discovered in the year 1812 by M. Courtois, a manufacturer of saltpetre at Paris.

CAROLINE.

And pray, Mrs. B., what proof is there of iodine being a simple body?

MRS. B.

It is considered as a simple body, both because it has resisted all attempts to resolve it into other ingredients, and because it is itself capable of combining with other bodies, in a manner analogous to oxygen and chlorine. The most singular of these combinations is that which it forms with hydrogen gas, the result of which is a peculiar gaseous acid, called hydriodic acid.

A third substance has been discovered in seawater, which bears a striking analogy to chlorine and iodine. M. Ballard, a French chemist, who discovered this body, called it BROME, from its poignant and disagreeable smell, much resembling that of chlorine.

This substance is a liquid of a dark red colour: it has the property of corroding both animal and vegetable matters: its poisonous effects are so active, that a single drop poured into the bill of a bird kills it instantaneously. It is remarkably heavy; its specific gravity being three times that of water.

CAROLINE.

Then I suppose that it requires a very considerable heat to produce ebullition?

MRS. B.

No; brome forms a singular exception to the

general law; for, notwithstanding its high specific gravity, it boils at the temperature of 160° Fahrenheit.

CAROLINE.

That is very singular! and does it support combustion like chlorine?

MRS. B.

If you pour a drop of it into a glass jar, it is immediately filled with a red vapour, which extinguishes a lighted taper.

Brome, like chlorine and iodine, combines with hydrogen, forming *hydro-bromic acid*, and also with oxygen, and with several of the simple inflammable bodies. Its general properties seem to place it between chlorine and iodine; and the discovery of this body affords an additional confirmation of the simple nature of those two remarkable substances.

We have now examined such of the acids and salts as I conceived would appear to you interesting: but, before we conclude this subject, I must make you acquainted with the result of some very important experiments made by Mr. Faraday. As I have already had occasion to notice, this celebrated chemist has succeeded in condensing several of the gases, by the force of pressure, to a liquid state. His first attempts were upon chlorine, which he confined in a tube by means of a piston, acting as a condensing syringe: air was forced into the tube, until the pressure was equal to four times that of the atmosphere. Immediately

a clear yellow fluid was deposited, which proved to be liquid chlorine.

CAROLINE.

How could he ascertain the nature of the liquid whilst confined in the tube?

MRS. B.

He cut it through the middle, and the parts suddenly flew asunder, as if by an explosion: the whole of the yellow liquid disappeared, and a great quantity of chlorine gas was produced. Mr. Faraday has since succeeded, by means of a much more considerable pressure, in reducing to a fluid state all the gases which are susceptible of being absorbed by water; such as sulphuretted hydrogen gas, the carbonic, the muriatic acid, and even the nitrous oxide gas. The muriatic acid required a pressure of 40 atmospheres, the carbonic acid 36, and the nitrous oxide a pressure of no less than 50 atmospheres.

EMILY.

And have not similar experiments been made on the atmospheric air, which is so analogous in its composition to nitrous oxide gas?

MRS. B.

No one has yet succeeded in reducing to a fluid state either atmospherical air or oxygen gas; but it is possible that, by employing a pressure more considerable than that hitherto used, the liquefaction of these gases may be accomplished.

EMILY.

But, Mrs. B., is it possible to produce such an immense pressure by means of a condensing syringe?

MRS. B.

No, it is not. Another mode was used by Mr. Faraday to obtain the liquefaction of the gases: he introduced into a very strong glass tube the materials requisite for their formation, and generated them in such quantities within the tube as to produce the requisite degree of condensation and pressure. The carbonic acid gas was first condensed into a liquid by Mr. Thilorion. He found means of producing it in a strong iron vessel, in which, as it could not escape, it became condensed in proportion as it was generated, until it was at length reduced to a liquid. This liquid was then allowed to evaporate, which occasioned so great an absorption of caloric, that while the carbonic acid which evaporated was converted into a gas, that which remained in the iron vessel was frozen.

CAROLINE.

How very strange that at the very same moment one part of the liquid should be changed into air and the other into a solid body!

EMILY.

Not if you reflect upon it, for one is the simple and natural consequence of the other. It is the latent caloric passing from one part of the liquid

into the other, which freezes the one and converts the other into a gas.

And pray what did the frozen carbonic acid look like?

MRS. B.

It resembled flakes of snow, and in this state Mr. Faraday made use of it as a means of producing a still greater intensity of cold, with the view of condensing and liquefying other gases. For this purpose he mixed the flakes of carbonic acid with ether (the most volatile of all liquids) in the receiver of the air pump, and then added great pressure; and by these means he succeeded in liquefying six gases which had never before been brought to that state, and he reduced seven gases to a solid form; among these were ammonia, nitrous acid, and sulphuretted hydrogen. These bodies when solid are as colourless and transparent as the clearest ice.

EMILY.

Wonderful! How much I should like to see this curious process!

MRS. B.

You will be able to do so when you attend Mr. Faraday's lectures at the Royal Institution.

CAROLINE.

But were not the oxygen, nitrogen, and hydrogen gases among those which were rendered liquid or solid?

MRS. B.

No; these bodies resisted all Mr. Faraday's efforts, though he subjected the oxygen gas to a pressure of 58 atmospheres, the nitrogen to one of 27, and the hydrogen to 50, with the addition of the frigorific process I mentioned.

CAROLINE.

Well, I am very sorry he did not subdue these refractory gases; but I doubt not but that he will soon be able to reduce them to obedience.

MRS. B.

It is now time to conclude: I shall not enter into any particulars respecting the metallic acids, as they offer nothing sufficiently striking for our present purpose.

CONVERSATION XIX.

ON THE NATURE AND COMPOSITION OF VEGETABLES.

MRS. B.

WE have hitherto treated only of the simplest combinations of elements, such as alkalies, earths, acids, compound salts, stones, &c., all of which belong to the mineral kingdom. It is time now to turn our attention to a more complicated class of compounds, that of ORGANISED BODIES, which will furnish us with a new source of instruction and amusement.

EMILY.

By organised bodies I suppose you mean the vegetable and animal creation? I have, however, but a very vague idea of the word *organisation*, and I have often wished to know more precisely what it means.

MRS. B.

Organised bodies are such as are endowed by nature with various parts, peculiarly constructed, and adapted to perform certain functions connected

with life. Mineral compounds are formed by the simple effect of mechanical or chemical attraction, and might appear to some to be the productions of chance; whilst organised bodies bear the most striking and impressive marks of design, and are eminently distinguished by that unknown principle, called *life*, from which the various organs derive the power of exercising their respective functions.

CAROLINE.

But in what manner does life enable these organs to perform their several functions?

MRS. B.

That is a mystery which is enveloped in such profound darkness, that I fear there is very little hope of our ever being able to unfold it. It rests in the bosom of a wise and beneficent Creator, and we must content ourselves with examining the effects of this principle: with regard to life itself, we have been able only to give it a name, without attaching any other meaning to it, than the vague and unsatisfactory idea of an unknown agent.

CAROLINE.

And yet I think I can form a very clear idea of life.

MRS. B.

Pray let me hear how you would define it?

CAROLINE.

It is, perhaps, more easy to conceive than to express: let me consider. Is not life the power

which enables both the animal and the vegetable creation to perform the various functions which nature has assigned to them?

MRS. B.

I have nothing to object to your definition; but you will allow me to observe, that you have only mentioned the effects which the unknown cause produces, without giving us any notion of the cause itself.

EMILY.

Yes, Caroline; you have told us what life *does*, but you have not told us what it *is*.

MRS. B.

We may study its operations; but we should perplex ourselves to no purpose by attempting to form an idea of its real nature.

We shall begin with examining its effects in the vegetable world, which constitutes the simplest class of organised bodies: these we shall find distinguished from the mineral creation, not only by their more complicated nature, but by the power which they possess within themselves of forming new chemical arrangements of their constituent parts by means of appropriate organs. Thus, though all vegetables are ultimately composed of hydrogen, carbon, and oxygen, with sometimes a little nitrogen, they separate and combine these principles, by their various organs, in a thousand ways, and form, with them, different kinds of

juices and solid parts, which exist ready-made in vegetables, and may, therefore, be considered as their immediate materials.

These are : —

<i>Sap,</i>	<i>Resins,</i>
<i>Mucilage,</i>	<i>Gum Resins,</i>
<i>Sugar,</i>	<i>Balsams,</i>
<i>Starch,</i>	<i>Caoutchouc,</i>
<i>Gluten,</i>	<i>Extractive colouring Matter,</i>
<i>Fixed Oil,</i>	<i>Tannin,</i>
<i>Volatile Oil,</i>	<i>Woody Fibre,</i>
<i>Camphor,</i>	<i>Vegetable Acids, &c.</i>

CAROLINE.

What a long list of names ! I did not suppose that a plant was composed of half so many ingredients.

MRS. B.

You must not imagine that every one of these materials is formed in each individual plant. I only mean to say, that they are all derived exclusively from the vegetable kingdom.

EMILY.

But does each particular part of the plant, such as the root, the bark, the stem, the seeds, the leaves, consist of one of these ingredients only, or of several of them combined together ?

MRS. B.

There is no part of a plant which can be said to consist solely of any one particular ingredient : a

certain number of vegetable materials must always be combined for the formation of any particular part (of a seed for instance); and these combinations are carried on by sets of vessels, or minute organs, which select from other parts, and bring together, the several elements required for the developement and growth of those particular parts which they are intended to form and to maintain.

EMILY.

And are not these combinations always regulated by the laws of chemical attraction?

MRS. B.

No doubt: the organs of plants cannot force principles to combine which have no attraction for each other; nor can they compel superior attractions to yield to those of inferior power: they probably act rather mechanically, by bringing into contact such elements, and in such proportions, as will, by their chemical combination, form the various vegetable products.

CAROLINE.

We may, then, consider each of these organs as a curiously constructed apparatus, adapted by its mechanism for the performance of a variety of chemical processes.

MRS. B.

Exactly so. As long as the plant lives and thrives, the carbon, hydrogen, nitrogen, and

oxygen (the chief constituents of its immediate materials), are so balanced and connected together that they are not susceptible of entering into other combinations; but no sooner does death take place than this state of equilibrium is destroyed, and new combinations are produced.

EMILY.

But why should death destroy it; for these elements must remain in the same proportions, and consequently, I should suppose, in the same order of attractions?

MRS. B.

You must remember, that in the vegetable, as well as in the animal kingdom, it is the principle of *life* which enables the organs to act; when deprived of that agent or stimulus their power ceases, and an order of attractions succeeds similar to that which would take place in mineral or unorganised matter.

EMILY.

And it is this new order of attractions, I suppose, that destroys the organisation of the plant after death; for if the same combinations still continued to prevail, the plant would always remain in the state in which it died.

MRS. B.

And that, you know, is never the case: plants may be partially preserved for some time after death by drying; but, in the natural course of events, they all return to the state of simple ele-

ments; a wise and admirable dispensation of Providence, by which dead plants are rendered fit to enrich the soil, and become subservient to the nourishment of living vegetables.

CAROLINE.

But we are talking of the dissolution of plants before we have examined them in their living state.

MRS. B.

Because I wished to give you a general idea of the nature of vegetation before we entered into particulars. Besides, it is not so irrelevant as you suppose to talk of vegetables in their dead state, since we cannot analyse them without destroying life; and it is only by hastening to submit them to examination, immediately after they have ceased to live, that we can anticipate their natural decomposition. There are two kinds of analysis of which vegetables are susceptible; first, that which separates them into their immediate materials, such as sap, resin, mucilage, &c.; secondly, that which decomposes them into their primitive elements, as carbon, hydrogen, nitrogen, and oxygen.

EMILY.

Is there not a third kind of analysis of plants, which consists in separating their various parts, as the stem, the leaves, and the several organs of the flower?

MRS. B.

That, my dear, is the department of the botanist;

and you must remember that I am not teaching you botany, but simply making you acquainted with the chemical composition and products of vegetables; we shall, therefore, consider these different parts of plants only as the organs by which the various secretions or separations are performed; but we must first examine the nature of these secretions.

The sap, which the roots suck up from the soil, consists of water holding in solution the various ingredients which are to nourish the plant. These it conveys to the leaves, where they are transformed into vegetable materials, and in that state are brought by the descending sap to the several organs they are destined to nourish, and deposited in them. This is a slight outline of the manner in which plants receive food from the soil; but as we proceed, you will find that it is not the only source whence they derive sustenance.

Mucus or *mucilage* is a vegetable substance, which, like all the others, is secreted from the sap by the leaves; when in excess it exudes from trees in the form of gum.

CAROLINE.

Is that the gum so frequently used instead of paste or glue?

MRS. B.

It is: almost all fruit-trees yield some sort of gum; but that most commonly used in the arts is obtained from a species of acacia-tree in Arabia,

and is called *gum arabic*: it forms the chief nourishment of the natives of those parts, who obtain it in great quantities from incisions which they make in the trees.

CAROLINE.

I did not know that gum was eatable.

MRS. B.

It is very nutritious. There is an account of a whole ship's company being saved from starving by feeding on the cargo, which was gum senegal; but I should not imagine that it would be either a pleasant or a particularly eligible diet to those who have not, from their birth, been accustomed to it. It is, besides, frequently taken medicinally. Several kinds of vegetable acids may be obtained, by particular processes, from gum or mucilage, the principal of which is called the *mucous acid*.

Sugar is not found in its simple state in plants; but is always mixed with gum, sap, or other ingredients: this saccharine matter is to be met with in every vegetable, but abounds most in roots, such as the beet-root and parsnips; in fruits, in which when ripe it is almost universal, but the plant which produces it in greatest abundance is the sugar-cane.

EMILY.

If all vegetables contain sugar, why is it extracted exclusively from the sugar-cane?

MRS. B.

Because it is both most plentiful and most easily

obtained from that plant. Besides, the sugars produced by other vegetables differ a little in their nature.

During the prevalence of Bonaparte's prohibitory system, which deprived his subjects of the use of West Indian produce, several attempts were made to extract sugar from other vegetables, and very good sugar was obtained from parsnips and from beet-root; and the process has since been carried to such a state of perfection, as to enable the beet-root sugar by paying a less duty to compete for many years with that of the sugar-cane of the West Indian Islands.

CAROLINE.

I should think that sugar might be more easily obtained from sweet fruits, such as figs, dates, &c.

MRS. B.

Probably; but it would be still more expensive, from the high price of those fruits, and it would not be crystallised like common sugar.* There are several varieties of sugar besides that extracted from the cane; the most remarkable of these is called grape sugar, and is found in fruits, and in

* Some foreign chemists (MM. Kirkoff, Braconnot, &c.) have found that if starch be boiled for a long time in water containing one fortieth part of sulphuric acid, and evaporated down to a certain consistence, the solution of starch concretes in cooling into a solid brownish mass, which has the taste and other general properties of sugar, and is of the same nature as grape sugar. During this process no gas is disengaged, and the acid is not decomposed.

the nectary of flowers. It does not crystallise, but looks like liquid sugar mixed with flour. It is very similar to treacle. The common property of all saccharine matter, that is, the various descriptions of sugars, is to ferment with water and leaven, and to produce alcohol or spirit of wine.

EMILY.

Pray, in what manner is sugar obtained from the sugar-cane?

MRS. B.

The juice of this plant is first pressed out by passing it between two cylinders of iron. It is then boiled with lime-water, which makes a thick scum rise to the surface. The clarified liquor is let off below, and evaporated to a very small quantity; after which it is suffered to crystallise, by standing in a vessel, the bottom of which is perforated with holes, which are imperfectly stopped, in order that the syrup may drain off. The sugar obtained by this process is a coarse brown powder, commonly called raw or moist sugar: it undergoes another operation to be refined and converted into loaf-sugar. There are two modes of doing this; the ancient one was to dissolve the raw sugar in water, and afterwards purify by an animal fluid called albumen. White of eggs chiefly consists of this fluid, which is also one of the constituent parts of blood; and, consequently, eggs, or bullock's blood, are commonly used for this purpose.

The albuminous fluid, being diffused through the syrup, combines with all the solid impurities contained in it, and rises with them to the surface, where it forms a thick scum: the clear liquor is then again evaporated to a proper consistence, and poured into moulds, in which, by an imperfect crystallisation, it forms loaf-sugar. But an additional process is required to whiten it; for which purpose the mould is inverted, and its open base is covered with clay, through which water is made to pass; the water, slowly trickling through the sugar, combines with and carries off the colouring matter.

CAROLINE.

I am very glad to hear that the blood which is used to purify sugar does not remain in it, it is such a disagreeable idea. And what is the other mode of refining sugar?

MRS. B.

The other process, which we owe to the late Mr. Howard, has completely superseded the old one, at least in this country. It would be much too long to give you an account of it in detail; but the principal improvement relates to the mode of evaporating the syrup, in order to bring it to the consistency of sugar. Instead of boiling the syrup in a large copper, over a strong fire, the water is carried off by means of an air-pump, in a way similar to that used in Mr. Leslie's experiment for

freezing water by evaporation ; that is, the syrup being exposed to a vacuum, the water evaporates quickly, with no greater heat than that of a little steam, which is introduced round the boiler. The air-pump is of course of large dimensions, and is worked by a steam-engine. A great saving is thus obtained, and a striking instance afforded of the power of science in suggesting useful economical improvements.

EMILY.

And pray how are sugar-candy and barley-sugar prepared ?

MRS. B.

Candied sugar is nothing more than the regular crystals, obtained by slow evaporation from a solution of sugar. Barley-sugar is sugar melted by heat, and afterwards cooled in moulds of a spiral form.

Sugar may be decomposed by a red heat, and, like all other vegetable substances, resolved into carbonic acid and hydrogen. The formation and the decomposition of sugar afforded many very interesting particulars, which we shall fully examine, after having gone through the other materials of vegetables. We shall find that there is reason to suppose that sugar is not, like the other materials, secreted from the sap by appropriate organs, but that it is formed by a peculiar process, with which you are not yet acquainted.

CAROLINE.

Pray, is not honey of the same nature as sugar?

MRS. B.

Honey is a mixture of saccharine matter and grape sugar.

EMILY.

I thought that honey was in some measure an animal substance, as it is prepared by the bees.

MRS. B.

It is rather collected by them from flowers, and conveyed to their storehouses, the hives. It is the wax only that undergoes a real alteration in the body of the bee, and is thence converted into an animal substance.

Manna is another kind of sugar, which is united with a nauseous extractive matter, to which it owes its peculiar taste and colour. It exudes like gum from various trees in hot climates, some of which have their leaves glazed by it.

The next of the vegetable materials is starch; this substance is contained in all seeds, and in some roots; of its formation I shall speak hereafter. It is intended by nature for the first aliment of the young vegetable; but that of one particular grain is become a favourite and most common food of a large part of mankind.

EMILY.

You allude, I suppose, to bread, which is made of wheat-flour.

MRS. B.

Yes. The grain of wheat contains also another vegetable substance, which seems peculiar to that seed, or, at least, has not as yet been obtained from any other; this is *gluten*, which is of a sticky, ropy, elastic nature; and it is owing to the viscous qualities of this substance that wheat-flour forms a much better paste than any other.

EMILY.

Gluten, by your description, must be very like gum?

MRS. B.

They are both of a sticky nature; but gluten is essentially different from gum in other points; and especially in its being insoluble in water, whilst gum, you know, very easily melts. Gluten may also be distinguished from gum, and, indeed, from most other vegetable substances, by its containing a considerable quantity of nitrogen.

The oils in vegetables consist of hydrogen and carbon, combined in various proportions.

EMILY.

And I think you said that animal oils were also formed of the same ingredients?

MRS. B.

The essential constituent parts of either vegetable or animal oils are the same; their variety arises from the different proportions of hydrogen and carbon, and from other accessory ingredients

which may be mixed with them. The oil of a whale and the oil of roses are, in their essential constituent parts, the same; but the one is impregnated with the offensive particles of animal matter, the other with the delicate perfume of a flower.

The difference of *fixed oils* and *volatile* or *essential oils* consists also in the various proportions of carbon and hydrogen. Fixed oils are those which will not evaporate without being decomposed; this is the case with all common oils, which contain a greater proportion of carbon than the essential oils. The essential oils (which comprehend the whole class of essences and perfumes) are lighter; they contain more equal proportions of carbon and hydrogen, and are volatilised or evaporated without being decomposed.

EMILY.

When you say that one kind of oil will evaporate, and the other be decomposed, you mean, I suppose, by the application of heat?

MRS. B.

Not necessarily; for there are oils which will evaporate slowly at the common temperature of the atmosphere; but for a more rapid volatilisation, or for their decomposition, the assistance of heat is required.

In fixed oils the carbon preponderates, and the heat produces a decomposition; while in essential

oils the proportion of hydrogen is greater, and heat produces a volatilisation only.

EMILY.

I suppose the reason why oil burns so well in lamps is owing to its two constituents, hydrogen and carbon, being so combustible?

MRS. B.

Certainly: the combustion of oil is perfectly similar to that of a candle; if tallow, it is only oil in a concrete state; if wax, or spermaceti, its chief chemical ingredients are still hydrogen and carbon.

EMILY.

I wonder, then, there should be so great a difference between tallow and wax.

MRS. B.

I must again repeat, that the same substances, in different proportions, produce results which have sometimes scarcely any resemblance to each other. But this is rather a general remark, that I wish to impress upon your minds, than one which is applicable to the present case; for tallow and wax are far from being very dissimilar; the chief difference consists in the wax being a purer compound of carbon and hydrogen than the tallow, which retains more of the gross particles of animal matter. The combustion of a candle, and that of a lamp, both produce water and carbonic acid gas. Can you tell me how these are formed?

EMILY.

Let me reflect: both the candle and lamp burn by means of fixed oil; this is decomposed as the combustion goes on; and the constituent parts of the oil being thus separated, the carbon unites with a portion of oxygen from the atmosphere to form carbonic acid gas, whilst the hydrogen combines with another portion of oxygen, and forms with it water. The products, therefore, of the combustion of oils, whether animal or vegetable, are water and carbonic acid gas.

CAROLINE.

But we see neither water nor carbonic acid produced by the combustion of a candle.

MRS. B.

The carbonic acid gas, you know, is invisible, and the water, being in a state of vapour, is so likewise, and Emily is perfectly correct in her explanation.

Fixed oil is contained only in the seeds of plants, excepting in the olive, in which it is produced and expressed from the fruit. We have already observed that seeds contain, also, starch; these two substances, united with a little mucilage, form the white substance contained in the seeds or kernels of plants, which is destined for the nourishment of the young plant to which the seed gives birth. The milk of almonds, which is expressed from the seed of that name, is composed of these three substances.

EMILY.

Pray, of what nature is the linseed oil which is used in painting?

MRS. B.

It is a fixed oil, obtained from the seed of flax. Nut oil, which is frequently used for the same purpose, is expressed from walnuts.

Olive oil is that which is best adapted to culinary purposes.

CAROLINE.

And what are the oils used for burning?

MRS. B.

Animal oils, most commonly; but the preference given to them is owing to their being less expensive; for vegetable oils burn equally well, and are more pleasant, their smell being less offensive.

EMILY.

Since oil is so good a combustible, why do lamps so frequently require trimming?

MRS. B.

This sometimes proceeds from the construction of the lamp, which may not be sufficiently favourable to a perfect combustion; but there is certainly a defect in the nature of oil itself, which renders it necessary for the best-constructed lamps to be occasionally trimmed. This defect arises from a portion of mucilage, which it is extremely difficult to separate from the oil, and which, being a bad combustible, gathers round the wick, and

1

thus impedes its combustion, and, consequently, dims the light.

CAROLINE.

But will not oils burn without a wick ?

MRS. B.

Not unless their temperature be elevated to five or six hundred degrees ; the wick answers this purpose, as I think I once before explained to you. The oil rises between the fibres of the cotton by capillary attraction, and the heat of the burning wick volatilises it, and brings it successively to the temperature at which it is combustible.

EMILY.

I suppose the explanation which you have given, with regard to the necessity of trimming lamps, applies also to tallow candles, which so often require snuffing.

MRS. B.

It does ; at least, in some degree. But besides the circumstance just explained, the common sorts of oils are not very highly combustible ; so that the heat produced by a candle, which is a coarse kind of animal oil, being insufficient to volatilise them completely, a quantity of soot is gradually deposited on the wick, which dims the light, and retards the combustion.

CAROLINE.

Wax candles, then, contain no incombustible matter, since they do not require snuffing ?

MRS. B.

Wax is a much better combustible than tallow, but still not perfectly so, since it likewise contains some particles that are unfit for burning; but when these gather round the wick (which in a wax light is comparatively small), they weigh it down on one side, and fall off together with the burnt part of the wick.

CAROLINE.

As oils are such good combustibles, I wonder that they should require so great an elevation of temperature before they begin to burn?

MRS. B.

Though fixed oils will not enter into actual combustion below the temperature of about four hundred degrees, yet they will slowly absorb oxygen at the common temperature of the atmosphere. Hence arises a variety of changes in oils which modify their properties and uses in the arts.

If oil simply absorbs and combines with oxygen, it thickens and changes to a kind of wax. This change is observed to take place on the external parts of certain vegetables even during their life. But it happens, in many instances, that the oil does not retain all the oxygen which it attracts, but that part of it combines with, or burns, the hydrogen of the oil; thus forming a quantity of water, which gradually goes off by evaporation. In this case the alteration of the oil consists not

only in the addition of a certain quantity of oxygen, but in the diminution of the hydrogen. These oils are distinguished by the name of *drying oils*. Linseed, poppy, and nut oils, are of this description.

EMILY.

I am well acquainted with drying oils, as I continually use them in painting. But I do not understand why the acquisition of oxygen on one hand, and a loss of hydrogen on the other, should render them drying.

MRS. B.

This may arise from two reasons: either from the oxygen which is added being less favourable to the state of fluidity than the hydrogen which is subtracted; or from the additional quantity of oxygen giving rise to new combinations, in consequence of which the most fluid parts of the oil are liberated and volatilised.

For the purpose of painting, the drying quality of oil is further increased by adding a quantity of oxide of lead to it, by which means it is more rapidly oxygenated.

The rancidity of oils is likewise owing to their oxygenation. In this case a new order of attraction takes place, from which a peculiar acid is formed, called the *sebacic acid*.

CAROLINE.

Since the nature and composition of oil is so

well known, pray could not oil be actually *made* by combining its principles?

MRS. B.

That is by no means a necessary consequence ; for there are innumerable varieties of compound bodies which we can decompose, although we are unable to reunite their ingredients. This, however, is not the case with oil ; as it has very lately been discovered that it is possible to form oil, by a peculiar process, from the action of oxygenated muriatic acid gas on hydro-carbonate.

We now pass to the *volatile* or *essential oils*. These form the basis of all the vegetable perfumes, and are contained, more or less, in every part of the plant excepting the seed ; they are, at least, never found in that part of the seed in which the embryo plant is situated.

EMILY.

The smell of flowers, then, proceeds from volatile oil?

MRS. B.

Certainly ; but this oil is often most abundant in the rind of fruits, as in oranges, lemons, &c., from which it may be extracted by the slightest pressure : it is found also in the leaves of plants, and even in the wood.

CAROLINE.

Is it not very plentiful in the leaves of mint and of thyme, and all the sweet-smelling herbs?

MRS. B.

Yes, remarkably so: and in geranium leaves also, which have a much more powerful odour than the flowers.

The perfume of sandal fans is an instance of its existence in wood. In short, all vegetable odours or perfumes are produced by the evaporation of particles of these volatile oils.

EMILY.

They are, I suppose, very light, and of very thin consistence, since they are so volatile?

MRS. B.

They vary very much in this respect, some of them being as thick as butter, whilst others are as fluid as water. In order to be prepared for perfumes, or essences, these oils are first properly purified, and then either distilled with spirit of wine, as is the case with lavender-water, or simply mixed with a large proportion of water, as is often done with regard to peppermint. Frequently, also, these odoriferous waters are prepared merely by soaking the plants in water, and distilling. The water then comes over impregnated with the volatile oil.

CAROLINE.

Such essences are frequently used to take spots of grease out of cloth or silk:—how do they produce that effect?

MRS. B.

By combining with the substance which forms these stains; for volatile oils, and likewise the spirit in which they are distilled, will dissolve wax, tallow, spermaceti, and resins: if, therefore, the spot proceeds from any of these substances, it will remove it. Insects of every kind have a great aversion to perfumes, so that volatile oils are employed with success in museums for the preservation of stuffed birds and other species of animals.

CAROLINE.

Pray, does not the powerful smell of camphor proceed from a volatile oil?

MRS. B.

Camphor seems to be a substance of its own kind, remarkable by many peculiarities. But if not exactly of the same nature as volatile oil, it is at least very analogous to it. It is obtained chiefly from the camphor-tree, a species of laurel which grows in China and in the Indian isles, from the stem and roots of which it is extracted. Small quantities have also been distilled from thyme, sage, and other aromatic plants; and it is deposited in pretty large quantities by some volatile oils after long standing. It is extremely volatile and inflammable. It is insoluble in water, but is soluble in alcohol and in oils; in which state, as well as in its solid form, it is frequently applied to medicinal

purposes. Amongst the peculiar properties of camphor, there is one too singular to be passed over in silence. If you take a small piece of camphor, and place it on the surface of a basin of pure water, it will immediately begin to move round and round with great rapidity; but if you pour into the basin a single drop of any odoriferous fluid, it will instantly put a stop to this motion. You can at any time try so very simple an experiment; but you must not expect that I shall be able to account for the phenomenon, as nothing satisfactory has yet been advanced for its explanation.

CAROLINE.

It is very singular, indeed; and I will certainly make the experiment. Pray what are *resins*, which you just now mentioned?

MRS. B.

They are volatile oils, which have been peculiarly modified by the action of oxygen on them.

CAROLINE.

They are, therefore, oxygenated volatile oils?

MRS. B.

Not exactly; for the process does not appear to consist so much in the oxygenation of the oil, as in the combustion of a portion of its hydrogen, and a small portion of its carbon. For when resins are artificially made by the combination of volatile oils with oxygen, the vessel in which the process is

performed is bedewed with water, and the air included within is loaded with carbonic acid.

EMILY.

This process must be, in some respects, similar to that for preparing drying oils?

MRS. B.

Yes: and it is by this operation that both of them acquire a greater degree of consistence. Pitch, tar, and turpentine, are the most common resins: they exude from the pine and fir trees. Copal, mastic, and frankincense, are also of this class of vegetable substances.

EMILY.

Is it of these resins that the mastic and copal varnishes, so much used in painting, are made?

MRS. B.

Yes. Dissolved either in oil, or in alcohol, resins form varnishes. From these solutions they may be precipitated by water, in which they are insoluble. This I can easily show you.—If you will pour some water into this glass of mastic varnish, it will combine with the alcohol in which the resin is dissolved, and the latter will be precipitated in the form of a white cloud.

EMILY.

It is so. And yet how is it that pictures or drawings, varnished with this solution, may safely be washed with water?

MRS. B.

As the varnish dries, the alcohol evaporates, and the dry varnish or resin which remains, not being soluble in water, will not be acted on by it.

There is a class of compound resins, called *gum resins*, which are precisely what their name denotes, that is to say, resins combined with mucilage. Myrrh and assafœtida are of this description.

CAROLINE.

Is it possible that a substance of so disagreeable a smell as assafœtida can be formed from a volatile oil?

MRS. B.

The odour of volatile oils is by no means always grateful. Onions and garlic derive their smell from volatile oils, as well as roses and lavender.

There is still another form under which volatile oils present themselves, which is that of *balsams*. These consist of resinous juices, combined with a peculiar acid, called the benzoic acid. Balsams appear to have been originally volatile oils, the oxygenation of which has converted one part into a resin, and the other part into an acid, which, combined together, form a balsam: such are the balsams of Peru, Tolu, &c.

We shall now take leave of the oils and their various modifications, and proceed to the next vegetable substance, which is *caoutchouc*. This is a white milky glutinous fluid, which acquires con-

sistence, and blackens in drying, in which state it forms the substance with which you are so well acquainted under the name of gum-elastic.

CAROLINE.

I am surprised to hear that gum-elastic was ever white, or ever fluid. And from what vegetable is it procured?

MRS. B.

It is obtained from two or three different species of trees, in the East Indies and South America, by making incisions in the stem. The juice is collected as it trickles from these incisions, and moulds of clay, in the form of little bottles of gum-elastic, are dipped into it. A layer of this juice adheres to the clay, and dries on it; and several layers are successively added by repeating this operation till the bottle is of sufficient thickness. It is then beaten to break down the clay, which is easily shaken out. The natives of the countries where this substance is produced sometimes make shoes and boots of it by a similar process; and they are said to be extremely pleasant and serviceable, both from their elasticity and their being water-proof. In civilised countries we employ it for similar purposes, but in a much more commodious manner. It dissolves into, and forms a sort of varnish, which excludes both air and water from any texture on which it is laid. It is applicable, therefore, to balloons, to keep them air-tight,

and to shoes, boots, great coats, or any other apparel, to render them water-proof.

The substance which comes next in our enumeration of the immediate ingredients of vegetables is *extractive matter*. This is a term which, in a general sense, may be applied to any substance extracted from vegetables; but it is more particularly understood to relate to the extractive *colouring matter* of plants. A great variety of colours are prepared from the vegetable kingdom, both for the purposes of painting and of dyeing: all the colours called *lakes* are of this description; but they are less durable than mineral colours, for by long exposure to the atmosphere they either darken or turn yellow.

EMILY.

I know that, in painting, the lakes are reckoned far less durable colours than the ochres; but what is the reason of it?

MRS. B.

The change which takes place in vegetable colours is owing, chiefly, to the oxygen of the atmosphere slowly burning their hydrogen, and leaving, in some measure, the blackness of the carbon exposed. Such change cannot take place in ochre, which is altogether a mineral substance.

Vegetable colours have a stronger affinity for animal than for vegetable substances; and this is supposed to be owing to a small quantity of nitrogen which they contain. Thus, silk and worsted

will take a much finer vegetable dye than linen and cotton.

CAROLINE.

Dyeing, then, is quite a chemical process?

MRS. B.

Undoubtedly. The condition required to form a good dye is, that the colouring matter should be precipitated, or fixed, on the substance to be dyed, and should form a compound not soluble in the liquids to which it will probably be exposed. Thus, for instance, printed or dyed linens or cottons must be able to resist the action of soap and water, to which they must necessarily be subject in washing; and woollens and silks should withstand the action of grease and acids, to which they may accidentally be exposed.

CAROLINE.

But if linen and cotton have not a sufficient affinity for colouring matter, how are they made to resist the action of washing, which they always do when well printed?

MRS. B.

When the substance to be dyed has either no affinity for the colouring matter, or not sufficient power to retain it, the combination is effected, or strengthened, by the intervention of a third substance, called a *mordant*, or basis. The mordant must have a strong affinity both for the colouring matter and the substance to be dyed, by which

means it causes them to combine and adhere together.

CAROLINE.

And what are the substances that perform the office of thus reconciling the two adverse parties?

MRS. B.

The most common mordant is sulphate of alumine, or alum. Oxides of tin and iron, in the state of compound salts, are likewise used for that purpose.

Tannin is another vegetable ingredient of great importance in the arts. It is obtained chiefly from the bark of trees ; but it is found also in nut-galls, and some other vegetables.

EMILY.

Is that the substance commonly called *tan*, which is used in hot-houses?

MRS. B.

Tan is the prepared bark in which the peculiar substance, tannin, is contained. But the use of tan in hot-houses is of much less importance than in the operation of *tanning*, by which skin is converted into leather.

EMILY.

Pray, how is this operation performed?

MRS. B.

Various methods are employed for this purpose, all of which consist in exposing skin to the action of tannin, or of substances containing this

principle in sufficient quantities, and disposed to yield it to the skin. The most usual way is to infuse coarsely-powdered oak-bark in water, and to keep the skin immersed in this infusion for a certain length of time. During this process, which is slow and gradual, the skin is found to have increased in weight, and to have acquired a considerable tenacity and impermeability to water. This effect may be much accelerated by using strong saturations of the tannin principle (which can be extracted from bark), instead of employing the bark itself. But this quick mode of preparation does not appear to make equally good leather.

Tannin is contained in a great variety of astringent vegetable substances, as galls, the rose-tree, and wine; but it is no where so plentiful as in bark. All these substances yield it to water, from which it may be precipitated by a solution of isinglass or glue, with which it strongly unites, and forms an insoluble compound. Hence its valuable property of combining with skin (which consists chiefly of glue), and of enabling it to resist the action of water.

EMILY.

Might we not see that effect by pouring a little melted isinglass into a glass of wine, which you say contains tannin?

MRS. B.

Yes. I have prepared a solution of isinglass for

that very purpose. Do you observe the thick muddy precipitate? That is the tannin combined with the isinglass.

CAROLINE.

This precipitate must then be of the same nature as leather?

MRS. B.

It is composed of the same ingredients; but, the organisation and texture of the skin being wanting, it has neither the consistence nor the tenacity of leather.

CAROLINE.

One might suppose that men who drink large quantities of red wine run some risk of having the coats of their stomachs converted into leather, since tannin has so strong an affinity for skin!

MRS. B.

It is not impossible but that the coats of their stomachs may be, in some measure, tanned, or hardened, by the constant use of this liquor; but you must remember, that where a number of other chemical agents are concerned, and, above all, where life exists, no certain chemical inference can be drawn.

I must not dismiss this subject without mentioning a discovery of Mr. Hatchett, who found that a substance very similar to tannin, possessing all its leading properties, and actually capable of tanning leather, may be produced by exposing car-

bon, or any substance containing carbonaceous matter, whether vegetable, animal, or mineral, to the action of nitric acid.

CAROLINE.

And is not this discovery of great use to manufactures?

MRS. B.

I fear not, because tannin thus artificially prepared must be more expensive than that which is obtained from bark. But the fact is extremely curious, as it affords one of those very rare instances of chemistry being able to imitate the proximate principles of organised bodies.

The last of the vegetable materials is *woody fibre*, which forms the whole of the cellular system, and is the hardest part of plants. The chief source from which this substance is derived is wood, but it is also contained, more or less, in every solid part of the plant. It forms a kind of skeleton of the part to which it belongs, and retains its shape after all the other materials have disappeared. It consists chiefly of carbon, united with a small proportion of salts, and the other constituents common to all vegetables.

EMILY.

It is of woody fibre, then, that the common charcoal is made?

MRS. B.

Yes. Charcoal, as you may recollect, is ob-

tained from wood by the separation of all its evaporable parts.

Before we take leave of the vegetable materials, it will be proper at least to enumerate the several vegetable acids which we either have had, or may have, occasion to mention. I believe I formerly told you that their basis, or radical, was uniformly composed of hydrogen and carbon, and that their difference consisted only in the various proportions of oxygen which they contained.

The following are the names of the principal vegetable acids:—

The *Mucous acid*, obtained from gum or mucilage;

Suberic from cork ;

Camphoric from camphor ;

Benzoic from balsams ;

Gallic from galls, bark, &c. ;

Malic from ripe fruits ;

Citric from lemon juice ;

Oxalic from sorrel ;

Succinic from amber ;

Tartaric from tartrate of potash ;

Moroxalic from white mulberries ;

Boletic from the juice of a species
of boletus ;

Kinic from Peruvian bark ;

Pyro-tartaric . . from tartaric acid ;

Pyro-citric . . . from citric acid ;

Pyro-malic . . . from malic acid ;

Acetic from vinegar.

They are all decomposable by heat, soluble in water, and turn vegetable blue colours red. The *camphoric*, the *succinic*, the *tartaric*, and the *acetic acids*, together with the *pyro-tartaric*, the *pyro-citric*, and the *pyro-malic acids*, which result from the application of heat to other vegetable acids, are the products of the decomposition of vegetables; we shall, therefore, reserve their examination for a future period.

The *oxalic acid*, distilled from sorrel, is the highest term of vegetable acidification, being almost entirely composed of carbon and oxygen, and containing only a very small proportion of hydrogen. If more oxygen be added to this substance, it loses its vegetable nature, and is resolved into carbonic acid and water; therefore, though all the other acids may be converted into the oxalic by an addition of oxygen, the oxalic itself is not susceptible of a further degree of oxygenation; nor can it be made, by any chemical process, to return to a state of lower acidification.

To conclude this subject, I have only to add a few words on the *gallic acid*. . . .

CAROLINE.

Is not this the same acid before mentioned, which forms ink, by precipitating sulphate of iron from its solution?

MRS. B.

Yes. Though it is usually extracted from galls,

on account of its being most abundant in that vegetable substance, it may also be obtained from a great variety of plants. It constitutes what is called the *astringent principle* of vegetables; it is generally combined with tannin; and you will find that an infusion of tea, coffee, bark, red wine, or any vegetable substance which contains the astringent principle, will make a black precipitate with a solution of sulphate of iron.

CAROLINE.

But pray what are galls?

MRS. B.

They are excrescences growing on the bark of young oaks, and are occasioned by an insect which wounds the bark of trees, and lays its eggs in the aperture. The lacerated vessels of the tree then discharge their contents, and form an excrescence, which affords a defensive covering for these eggs. The insect, when come to life, first feeds on this excrescence, and, some time afterwards, eats its way out, as it appears from a hole that is formed in all gall-nuts which no longer contain an insect. It is in hot climates only that strongly astringent gall-nuts are found; those which are used for the purpose of making ink are brought from Aleppo.

EMILY.

But are not the oak-apples, which grow on the

leaves of the oak in this country of a similar nature?

MRS. B.

Yes; only they are an inferior species of galls, containing less of the astringent principle, and therefore less applicable to these useful purposes.

EMILY.

Are the vegetable acids never found but in their pure uncombined state?

MRS. B.

On the contrary, they are frequently met with in the state of compound salts: these, however, are in general not so fully saturated with the salifiable bases, so that the acid predominates; in this state they are distinguished by the name of *acidulous* salts. Cream of tartar is a salt of this description.

CAROLINE.

Is not the salt of lemon commonly used to take out ink-spots and stains of this kind?

MRS. B.

No; that salt consists of the oxalic acid, combined with a little potash, though it commonly bears the name of salts of lemon. It is found in that state in sorrel; and it takes out ink-spots by uniting with the iron, and rendering it soluble in water.

Besides the vegetable materials which we have

enumerated, a variety of other substances, common to the three kingdoms, are found in vegetables; such as potash, which was formerly supposed to belong exclusively to plants, and was, in consequence, called the vegetable alkali.

Peculiar compounds are also met with in various plants, which, having many of the properties of alkalies, have obtained the name of *native vegetable alkalies*. The plants in which some of them reside in general produce very powerful, and even poisonous, effects upon the animal system, probably in consequence of the operation of these peculiar alkaline principles. Thus opium and other narcotic vegetable products contain a substance called *morphia*, which was first described by Derosne. The *nux vomica*, which is the fruit of the *Strychnos nux vomica* and of the *Strychnos ignatia*, yields a principle termed *strychnia*. From the leaves of the deadly nightshade, or *Atropa belladonna*, another alkaline substance, *atropia*, is obtained. *Veratria* is, in like manner, obtained from the *Veratrum album* and the *Colchicum autumnale*, or meadow saffron; *hyoscyama* from the *Hyoscyamus niger*, or henbane; and *nicotia* from the *Nicotiana tabacum* plant, the leaves of which produce snuff. All these substances act as powerful narcotics when taken, even in a very small quantity; and, in larger doses, are most deadly poisons. There are others which are not deleterious, and are derived from various barks, leaves, berries, and other parts of vegetables. Tea

and coffee both contain one of these alkaline substances, remarkable for the large proportion of nitrogen which enters into its composition, and to this is attributed the renovating influence of these *grateful restoratives*. The Peruvian bark affords two of these alkaline substances, *cinchonia* and *quinia*; and the bark of the *Brucea antidysenterica* yields *brucia*.*

EMILY.

Is this the quinine which has replaced bark in cases of ague or fever?

MRS. B.

Yes, it is. The quinine contained in bark appears to be the principle which interrupts the recurrence of intermitting fever: this is now separated from the bark by a chemical process; and it is no small advantage to be able to take any quantity of it, without encumbering the stomach with a useless load of the fibrous part of the bark.

It is chiefly from the resemblance which they bear to alkalies, in their power of neutralising acids, and of forming with them compounds analogous to other neutral salts, that these vegetable principles have been classed among alkalies. They

* These substances were at first distinguished by names ending in *ine*, as *morphine*, *strychnine*, &c.; but for the sake of conformity to the nomenclature of other alkalies, their names have since received a different termination.

have all, however, weaker affinities for acids than the ordinary alkalies; and are destructible, both when separate and in combination, at low degrees of heat.

Sulphur, phosphorus, earths, and a variety of metallic oxides, are also found in vegetables, but only in small quantities. And we meet also with neutral salts, formed by the combination of these ingredients.

CONVERSATION XX.

ON THE DECOMPOSITION OF VEGETABLES.

CAROLINE.

THE account which you have given us, Mrs. B., of the materials of vegetables, is doubtless very instructive; yet it does not completely satisfy my curiosity. What I wish particularly to know is, how plants obtain the principles from which their various materials are formed; by what means these are converted into vegetable matter; and how they are connected with the life of the plant.

MRS. B.

This implies nothing less than a complete history of the chemistry and physiology of vegetation*, the latter of which does not properly belong to our province. Still I hope that I shall be able, in some measure, to satisfy your curiosity. But, in order to render the subject more intelligible, I must first make you acquainted with the various changes which vegetables undergo, when the vital power no longer enables them to resist the common laws of chemical attraction.

* See Conversations on Vegetable Physiology.

The composition of vegetables being more complicated than that of minerals, the former more readily undergo chemical changes than the latter; for the greater the variety of attractions the more easily is the equilibrium destroyed, and a new order of combinations introduced.

EMILY.

I am surprised that vegetables should be so easily susceptible of decomposition; for the preservation of the vegetable kingdom is certainly far more important than that of minerals.

MRS. B.

It is no doubt with a view to the preservation of the vegetable kingdom, that nature has rendered plants so susceptible of disorganisation.

CAROLINE.

Oh, this is one of your paradoxes, Mrs. B. ! to destroy a thing in order to preserve it !

MRS. B.

The decomposition of the vegetable takes place, you know, only after the death of the plant, which, in the common course of nature, happens when it has yielded fruit and seeds to propagate its species. If, instead of thus finishing its career, each plant were to retain its form and vegetable state, it would become an useless burden to the earth and its inhabitants. When vegetables, therefore, cease

to be productive, they cease to live, and nature then begins her process of decomposition, in order to resolve them into their chemical constituents, hydrogen, carbon, oxygen, and nitrogen, — those simple and primitive ingredients which she keeps in store for all her combinations.

EMILY.

But since no system of combination can be destroyed, except by the establishment of another order of attractions, how can the decomposition of vegetables reduce them to their simple elements?

MRS. B.

It is a very long process, during which a variety of new combinations are successively established and successively destroyed; but in each of these changes the ingredients of vegetable matter tend to unite in a more simple order of compounds, till they are at length brought either to their elementary state, or at least to their most simple order of combinations. Thus you will find that vegetables are in the end almost entirely reduced to water and carbonic acid; the hydrogen and carbon dividing the oxygen between them, so as to form with it these two substances. But the variety of intermediate combinations, which take place during the several stages of the decomposition of vegetables, present us with a new set of compounds, well worthy of our examination.

CAROLINE.

Is it possible that vegetables, while putrefying, should produce any thing worthy of observation?

MRS. B.

They are susceptible of undergoing certain changes before they arrive at the state of putrefaction, which is the final term of decomposition; and of these changes we avail ourselves for particular and important purposes. But, in order to make you understand this subject, which is of considerable importance, I must explain it more in detail.

The decomposition of vegetables is always attended by a violent internal motion, produced by the disunion of one order of particles, and the combination of another. This is called FERMENTATION. There are several periods at which this process stops; so that a state of rest appears to be restored, and the new order of compounds fairly established. But, unless means be used to secure these new combinations in their actual state, their duration will be but transient, and a new fermentation will take place, by which the compound last formed will be destroyed: and another, and less complex order, will succeed.

EMILY.

The fermentations, then, appear to be only the successive steps by which a vegetable descends to its final dissolution.

MRS. B.

Precisely so. Your definition is perfectly correct.

CAROLINE.

And how many fermentations, or new arrangements, does a vegetable undergo, before it is reduced to its simple ingredients?

MRS. B.

Chemists do not exactly agree in this point; but there are, I think, four distinct fermentations, or periods, at which the decomposition of vegetable matter stops and changes its course. Every kind of vegetable matter is not, however, equally susceptible of undergoing all these fermentations.

There are likewise several circumstances required to produce fermentation. Water and a certain degree of heat are both essential to this process, in order to separate the particles, and by thus weakening the force of cohesion, enable the new chemical affinities to be brought into action.

CAROLINE.

In frozen climates, then, how can the spontaneous decomposition of vegetables take place?

MRS. B.

It certainly cannot; and, accordingly, we find scarcely any vestiges of vegetation where a constant frost prevails.

CAROLINE.

One would imagine, that, on the contrary, such spots would be covered with plants; for, since

they cannot be decomposed, their number must always increase.

MRS. B.

But, my dear, heat and water are quite as essential to the formation of vegetables as they are to their decomposition. Besides, it is from the dead vegetables, reduced to their elementary principles, that the rising generation is supplied with sustenance. No young plant, therefore, can grow, unless its predecessors contribute both to its formation and support; and these not only furnish the seed from which the new plant springs, but likewise the food by which it is nourished.

CAROLINE.

Under the torrid zone, therefore, where water is never frozen, and the heat is very great, both the processes of vegetation and of fermentation must, I suppose, be extremely rapid?

MRS. B.

Not so much as you imagine; for in such climates great part of the water which is required for these processes is in an aeriform state, which is scarcely more conducive either to the growth or the decomposition of vegetables than that of ice. In those latitudes, therefore, it is only in low damp situations, sheltered by woods from the sun's rays, that the smaller tribes of vegetables can grow and thrive during the dry season. Besides, dead vegetables, in such climates, seldom retain water enough

to produce fermentation, being soon dried up by the heat of the sun, which enables them to resist that process: so that it is not till the fall of the autumnal rains (which are very violent in the torrid zone) that spontaneous fermentation can take place.

The several fermentations derive their names from their principal products. The first is called the *saccharine fermentation*, because its product is *sugar*.

CAROLINE.

But sugar, you have told us, is found in all vegetables; it cannot, therefore, be the product of their decomposition.

MRS. B.

It is true that the saccharine fermentation is not confined to the decomposition of vegetables, as it continually takes place during their life; and, indeed, this circumstance has, till lately, prevented it from being considered as one of the fermentations. But the process appears so analogous to the other fermentations, and the formation of sugar, whether in living or dead vegetable matter, is so evidently a new compound, proceeding from the destruction of the previous order of combinations, and essential to the subsequent fermentations, that it is now, I believe, generally esteemed the first step, or necessary preliminary, to decomposition, if not an actual commencement of that process.

CAROLINE.

I recollect your hinting to us that sugar was supposed not to be secreted from the sap in the same manner as mucilage, starch, oil, and the other ingredients of vegetables.

MRS. B.

It is rather from these materials, than from the sap itself, that sugar is formed ; and it is developed at particular periods, as you may observe in fruits, which become sweet in ripening,—sometimes even after they have been gathered. Life, therefore, is not essential to the formation of sugar ; whilst, on the contrary, mucilage, starch, and the other vegetable materials which are secreted from the sap by appropriate organs, whose powers immediately depend on the vital principle, cannot be produced but during the existence of that principle.

EMILY.

The ripening of fruits is, then, their first step to destruction, as well as their last towards perfection.

MRS. B.

Exactly.—A process analogous to the saccharine fermentation takes place, also, during the cooking of certain vegetables. This is the case with parsnips, carrots, potatoes, &c. in which sweetness is developed by heat and moisture ; and we know that if we carry the process a little further, a more complete decomposition would ensue. The same process takes place also in seeds, previous to their sprouting.

CAROLINE.

How do you reconcile this to your theory, Mrs. B.? Can you suppose decomposition to be the necessary precursor of life?

MRS. B.

That is indeed the case. The materials of the seed must be decomposed, and the seed disorganised, before a plant can sprout from it. A seed, besides the embryo plant, contains (as we have already observed) starch, oil, and a little mucilage. These substances are destined for the nourishment of the future plant; but they undergo some change before they can be fit for this function. The seed, when buried in the earth, with a certain degree of moisture and of temperature, absorbs water, which dilates it, separates its particles, and introduces a new order of attractions, of which sugar is the product. The substance of the seed is thus softened, sweetened, and converted into a sort of white milky pulp, fit for the nourishment of the embryo plant.

EMILY.

This is very similar to the milk with which animals furnish their young.

MRS. B.

It is indeed. The saccharine fermentation of seeds is artificially produced, for the purpose of making *malt*, by the following process: — A quantity of barley is first soaked in water for two or

three days : the water being afterwards drained off, the grain heats spontaneously, swells, bursts, sweetens, shows a disposition to germinate, and actually sprouts to the length of an inch ; when the process is stopped by putting it into a kiln, where it is well dried at a gentle heat. In this state it is crisp and friable, and constitutes the substance called *malt*, which is the principal ingredient of beer.

EMILY.

But I hope you will tell us how malt is made into beer ?

MRS. B.

I must first explain to you the nature of the second fermentation, which is essential to that operation. This is called the *vinous fermentation*, because its product is *wine*.

EMILY.

How very different the decomposition of vegetables is from what I had imagined ! The products of their disorganisation appear almost superior to those which they yield during their state of life and perfection.

MRS. B.

And do you not at the same time admire the beautiful economy of Nature, which, whether she creates, or whether she destroys, directs all her operations to some useful and benevolent purpose ? — It appears that the saccharine fermentation is

extremely favourable, if not absolutely essential, as a previous step to the vinous fermentation ; so that if sugar be not developed during the life of the plant, the saccharine fermentation must be artificially produced before the vinous fermentation can take place. This is the case with barley, which does not yield any sugar until it be made into malt ; and in that state only is it susceptible of undergoing the vinous fermentation, by which it is converted into beer.

CAROLINE.

But if the product of the vinous fermentation be always wine, beer cannot have undergone that process, for beer is certainly not wine.

MRS. B.

Chemically speaking, beer may be considered as the wine of grain ; for it is the product of the fermentation of malt, just as wine is that of the fermentation of grapes or other fruits.

The consequence of the vinous fermentation is the decomposition of the saccharine matter, and the formation of a spirituous liquor from the constituents of the sugar. But, in order to promote this fermentation, not only water and a certain degree of heat are necessary, but also some other vegetable ingredients besides the sugar,—as starch, mucilage, acids, salts, extractive matter, &c. ; all of which seem to contribute to this process, and give to the liquor its peculiar taste.

EMILY.

It is, perhaps, for this reason that wine is not obtained from the fermentation of pure sugar; but that fruits are chosen for that purpose, as they contain not only sugar, but likewise the other vegetable ingredients which promote the vinous fermentation, and give the peculiar flavour.

MRS. B.

Certainly. And you must observe, also, that the relative quantity of sugar is not the only circumstance to be considered in the choice of vegetable juices for the formation of wine; otherwise the sugar-cane would be best adapted to that purpose. It is rather the manner and proportion in which the sugar is mixed with other vegetable ingredients that influence the production and qualities of wine. And it is found that the juice of the grape not only yields the most considerable proportion of wine, but that it likewise gives it the most grateful flavour.

EMILY.

I have seen a vintage in Switzerland, and I do not recollect that heat was applied, or water added, to produce the fermentation of the grapes.

MRS. B.

The common temperature of the atmosphere in the cellars in which the juice of the grape is fermented, is sufficiently warm for this purpose; and as the juice contains an ample supply of water, there is no occasion for any addition to it. But

when fermentation is produced in dry malt, a quantity of water must necessarily be added.

EMILY.

And what are precisely the changes which occur during the vinous fermentation ?

MRS. B.

The sugar is decomposed, and its constituents are recombined into two new substances : the one a peculiar liquid substance, called *alcohol*, or *spirit of wine*, which remains in the fluid ; the other, carbonic acid gas, which escapes during the fermentation. Wine, therefore, as I before observed, in a general point of view, may be considered as a liquid, of which alcohol constitutes the essential part. And the varieties of strength and flavour of the different kinds of wine are to be attributed to the different qualities of the fruits from which they are obtained, independently of the sugar.

CAROLINE.

I am astonished to hear that so powerful a liquid as spirit of wine should be obtained from so mild a substance as sugar.

MRS. B.

Can you tell me in what the principal difference consists between alcohol and sugar ?

CAROLINE.

Let me reflect ——— Sugar consists of carbon, hydrogen, and oxygen. If carbonic acid be subtracted from it during the formation of alcohol,

the latter will contain less carbon and oxygen than sugar does; therefore hydrogen must be the prevailing principle of alcohol.

MRS. B.

It is exactly so. And this very large proportion of hydrogen accounts for the lightness and combustible property of alcohol, and of spirits in general, all of which consist of alcohol variously modified.

EMILY.

And can sugar be recomposed from the combination of alcohol and carbonic acid?

MRS. B.

Chemists have never been able to succeed in effecting this; but from analogy I should suppose such a recomposition possible. Let us now observe more particularly the phenomena which take place during the vinous fermentation. At the commencement of this process heat is evolved, and the liquor swells considerably, owing to the formation of the carbonic acid, which is disengaged in such prodigious quantities as would be fatal to any person who should inspire it; an accident which has sometimes happened.

CAROLINE.

Oh yes; I have heard of accidents of this kind. I remember once a poor man falling into an empty brewing cask, and being suffocated by the fixed air which remained at the bottom.

MRS. B.

Fixed air, you know, is carbonic acid, which is so heavy a gas that, unless care be taken to empty the brewing casks of it, it will remain for a length of time at the bottom. If the fermentation be stopped by putting the liquor into barrels before the whole of the carbonic acid is evolved, the wine becomes brisk, like Champagne, in consequence of the carbonic acid imprisoned in it; and tastes sweet, like cyder, owing to the sugar not being completely decomposed.

EMILY.

I do not understand why heat should be evolved during this operation; for, as there is a considerable formation of gas, in which a proportionable quantity of heat must become insensible, I should have imagined that cold, rather than heat, would have been produced.

MRS. B.

So it appears on first consideration: but you must recollect that fermentation is a complicated chemical process; and that, during the decompositions and recompositions attending it, a quantity of chemical heat may be disengaged, sufficient both to develop the gas, and to effect an increase of temperature. When the fermentation is completed, the liquid cools and subsides, the effervescence ceases, and the thick, sweet, sticky juice of the fruit is converted into a clear, transparent, spirituous liquor, called wine.

EMILY.

How much I regret not having been acquainted with the nature of the vinous fermentation when I had an opportunity of seeing the process!

MRS. B.

You have an easy mode of satisfying yourself in that respect, by observing the process of brewing, which in every essential circumstance is similar to that of making wine, and is really a very curious chemical operation.

But though we cannot actually make wine at this moment, it will be easy to show you the mode of analysing it. This is done by distillation. When wine of any kind is submitted to this operation, it is found to contain brandy, water, tartar, extractive colouring matter, and some vegetable acids. I have put a little port wine into this alembic of glass (Plate XVII. fig. 1.), and on placing the lamp under it, you will soon see the spirit and water successively come over ——

EMILY.

But you do not mention alcohol amongst the *products* of the distillation of wine; and yet that is its most essential ingredient?

MRS. B.

The alcohol is contained in the brandy which is now coming over, and dropping from the still. Brandy is nothing more than a mixture of alcohol and water; and in order to obtain the alcohol pure, we must again distil it from brandy.

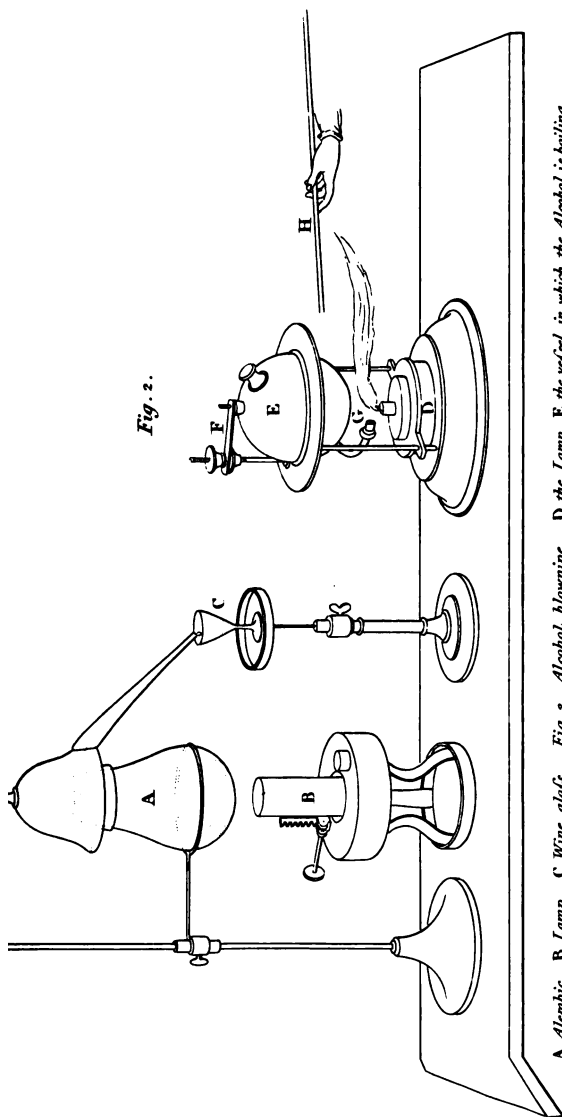


Fig. 2. A. Alembic. B. Lamp. C. Wine glass. D. the Lamp. E. the vessel in which the Alcohol is boiling. F. the stopcock. G. the inflamed jet or steam of alcohol directed towards a glass tube H.

Fig. 2. the Author.

Published by Longman & Co. Paternoster Row.

Engraved by Lowry.

1

1

1

CAROLINE.

I have just taken a drop on my finger : it tastes like strong brandy ; but it is without colour, whilst brandy is of a deep yellow.

MRS. B.

It is not so naturally : in its pure state, brandy is colourless, and it obtains the yellow tint you observe, by extracting the colouring matter from new oaken casks in which it has been kept. When it does not acquire the usual tinge in this way, it is customary to colour the brandy used in this country artificially, with a little burnt sugar, in order to give it the appearance of having been long kept.

CAROLINE.

And is rum also distilled from wine ?

MRS. B.

By no means ; it is distilled from the sugar-cane, a plant which contains so great a quantity of sugar, that it yields more alcohol than almost any other vegetable. After the juice of the cane has been pressed out for making sugar, what still remains in the bruised cane is extracted by water ; and this watery solution of sugar is fermented, and produces rum.

The spirituous liquor called *arrack* is in a similar manner distilled from the product of the vinous fermentation of rice.

EMILY.

But rice has no sweetness: does it contain any sugar?

MRS. B.

Like barley and most other seeds, it is insipid until it has undergone the saccharine fermentation; and this, you must recollect, is always a previous step to the vinous fermentation in those vegetables in which sugar is not already formed. Brandy may in the same manner be obtained from malt.

CAROLINE.

You mean from beer, I suppose: for the malt must have previously undergone the vinous fermentation.

MRS. B.

Beer is not precisely the product of the vinous fermentation of malt. For hops are a necessary ingredient for the formation of that liquor; whilst brandy is distilled from pure fermented malt. But brandy might, no doubt, be distilled from beer as well as from any other liquor that has undergone the vinous fermentation; for, since the basis of brandy is alcohol, it may be obtained from any liquid which contains that spirituous substance.

EMILY.

And, pray, from what vegetable is the favourite spirit of the lower orders of people—gin, extracted?

MRS. B.

The spirit (which is the same in all fermented liquors) may be obtained from any kind of grain ; but the peculiar flavour which distinguishes gin is that of juniper berries, which are distilled together with the grain.

I think the brandy contained in the wine which we are distilling must, by this time, be all come over. Yes — taste the liquor that is now dropping from the alembic——

CAROLINE.

It is perfectly insipid, like water.

MRS. B.

It is water, which, as I was telling you, is the second product of wine, and comes over after all the spirit, which is the lightest part, is distilled. — The tartar and extractive colouring matter we shall find in a solid form at the bottom of the alembic.

EMILY.

They look very like the lees of wine.

MRS. B.

And in many respects they are of a similar nature, for lees of wine consist chiefly of tartrate of potash ; a salt which exists in the juice of the grape, and in many other vegetables, and is developed only by the vinous fermentation. During this operation it is precipitated, and deposits itself on the internal surface of the cask in which the wine is contained. It is much used in medicine,

and in various arts, particularly dyeing, under the name of *cream of tartar* ; and it is from this salt that the tartaric acid is obtained.

CAROLINE.

But the medicinal cream of tartar is in appearance quite different from these dark-coloured dregs : it is perfectly colourless.

MRS. B.

Because it consists of the pure salt only, in its crystallised form ; whilst in the instance before us it is mixed with the deep-coloured extractive matter, and other foreign ingredients.

EMILY.

Pray, cannot we now obtain pure alcohol from the brandy which we have distilled ?

MRS. B.

We might ; but the process would be tedious : for, in order to obtain alcohol perfectly free from water, it is necessary to distil, or, as the distillers call it, *rectify*, it several times. You must, therefore, allow me to produce a bottle of alcohol which has been thus purified. This is a very important ingredient, which has many striking properties, besides its forming the basis of all spirituous liquors.

EMILY.

It is alcohol, I suppose, that produces intoxication ?

MRS. B.

Certainly: but the stimulus and momentary energy it gives to the system, and the intoxication it occasions when taken in excess, are circumstances not yet well accounted for. A course of very interesting experiments, however, was made at Paris some years ago, in which it was ascertained that alcohol affects only one individual portion of the brain, whose particular function it is to enable the body to maintain its equilibrium. So that if that part of the brain be taken away,—an experiment which was made on some small animals,—they reel and stagger, but do not appear otherwise to suffer.

CAROLINE.

That is very curious: I thought that spirits produced these effects by increasing the rapidity of the circulation of the blood; for drinking wine or spirits, I have heard, always quickens the pulse.

MRS. B.

No doubt: the spirit, by stimulating the nerves, increases the action of the muscles; and the heart, which is one of the strongest muscular organs, beats with augmented vigour, and propels the blood with accelerated quickness. After such a strong excitation, the frame naturally suffers a proportional degree of depression; so that a state of debility and languor is the invariable consequence of intoxication. But though these circumstances

are well ascertained, they are far from explaining why alcohol should produce such effects.

EMILY.

Liqueurs are the only kinds of spirits which I think pleasant. Pray of what do they consist?

MRS. B.

They are composed of alcohol, sweetened with syrup, and flavoured with volatile oil.

The different kinds of odoriferous spirituous waters are likewise solutions of volatile oil in alcohol; as lavender water, eau de Cologne, &c.

The chemical properties of alcohol are important and numerous. It is one of the most powerful chemical agents, and is particularly useful in dissolving a variety of substances which are soluble neither by water nor heat.

EMILY.

We have seen it dissolve copal and mastic to form varnishes; and these resins are certainly not soluble in water, since water precipitates them from their solution in alcohol.

MRS. B.

I am glad to find that you recollect these circumstances so well. The same experiment affords also an instance of another property of alcohol—its tendency to unite with water; for the resin is precipitated in consequence of losing the alcohol, which abandons it from its preference for water. It is attended also, as you may recollect, with the

same peculiar circumstance of a disengagement of heat and consequent diminution of bulk, which we have supposed to be produced by a mechanical penetration of particles by which latent heat is forced out.

Alcohol unites thus readily not only with resins and with water, but with oils and balsams: these compounds form the extensive class of elixirs, tinctures, quintessences, &c.

EMILY.

I suppose that alcohol must be highly combustible, since it contains so large a proportion of hydrogen?

MRS. B.

Extremely so; and it will burn at a very moderate temperature.

CAROLINE.

I have often seen both brandy and spirit of wine burnt; they produce a great deal of flame, but not a proportional quantity of heat, and no smoke whatever.

MRS. B.

The last circumstance arises from their combustion being complete; and the disproportion between the flame and heat shows you that these are by no means synonymous.

The great quantity of flame proceeds from the combustion of the hydrogen, to which, you know, that manner of burning is peculiar.—Have you

not remarked also that brandy and alcohol will burn without a wick?—They take fire at so low a temperature, that this assistance is not required to concentrate the heat and volatilise the fluid.

CAROLINE.

I have sometimes seen brandy burnt by merely heating it in a spoon.

MRS. B.

The rapidity of the combustion of alcohol may, however, be prodigiously increased by first volatilising it. An ingenious instrument has been constructed on this principle to answer the purpose of a blowpipe, which may be used for melting glass, or other chemical purposes. It consists of a small metallic vessel (Plate XVII. fig. 2.) of a spherical shape, which contains the alcohol, and is heated by the lamp beneath it: as soon as the alcohol is volatilised, it passes through the spout of the vessel, and issues just above the wick of the lamp, which immediately sets fire to the stream of vapour, as I shall show you.

EMILY.

With what amazing violence it burns! The flame of alcohol in the state of vapour is, I suppose, much hotter than when the spirit is merely burnt in a spoon?

MRS. B.

Yes; because in this way the combustion goes on more rapidly, and the heat is proportionally in-

creased.—Observe its effect on this small glass tube, the middle of which I present to the extremity of the flame, where the heat is greatest.

CAROLINE.

The glass, in that spot, is become red-hot, and bends from its own weight.

MRS. B.

I have now drawn it asunder, and am going to blow a ball at one of the heated ends : but I must previously close it up, and flatten it with this little metallic instrument, otherwise the breath would pass through the tube without dilating any part of it.—Now, Caroline, will you blow strongly into the tube while the closed end is red-hot ?

EMILY.

You blew too hard; for the ball suddenly dilated to a great size, and then burst in pieces.

MRS. B.

You will be more expert another time ; but I must caution you, should you ever use this blow-pipe, to be very careful that the combustion of the alcohol does not go on with too great violence, for I have seen the flame sometimes dart out with such force as to reach the opposite wall of the room, and set the paper on fire. There is, however, no danger of the vessel bursting, as it is provided with a safety tube, which affords an additional help for the vapour of alcohol when required.

The products of the combustion of alcohol consist, in a great proportion, of water, and a small quantity of carbonic acid. There is no smoke or fixed remains whatever.—How do you account for that, Emily?

EMILY.

I suppose that the oxygen which the alcohol absorbs in burning converts its hydrogen into water, and its carbon into carbonic acid gas, and thus it is completely consumed.

MRS. B.

Very well.—*Ether*, the lightest of all fluids, and with which you are well acquainted, is obtained from alcohol, of which it forms the lightest and most volatile part.

EMILY.

Ether, then, is to alcohol what alcohol is to brandy?

MRS. B.

No: there is an essential difference. In order to obtain alcohol from brandy, you need only deprive the latter of its water; but for the formation of ether, the alcohol must be decomposed, and one of its constituents partly subtracted. I leave you to guess which of them it is.

EMILY.

It cannot be hydrogen, as ether is more volatile than alcohol, and hydrogen is the lightest of all its ingredients: nor do I suppose that it can be

oxygen, as alcohol contains so small a proportion of that principle; it is, therefore, most probably, carbon, a diminution of which would not fail to render the new compound more volatile.

MRS. B.

You are perfectly right. The formation of ether consists simply in subtracting from the alcohol a certain proportion of carbon: this is effected by the action of the sulphuric, nitric, or muriatic acids, on alcohol. The acid and carbon remain at the bottom of the vessel, whilst the decarbonised alcohol flies off in the form of a condensable vapour, which is ether.

Ether is the most inflammable of all fluids, and burns at so low a temperature, that the heat evolved during its combustion is more than is required for its support; so that a quantity of ether is volatilised, which takes fire, and gradually increases the violence of the combustion.

Sir Humphry Davy discovered a very singular fact respecting the vapours of alcohol and ether. If a few drops of ether be poured into a wine-glass, and a fine platina wire, heated almost to redness, be held suspended in the glass, close to the surface of the ether, the wire soon becomes intensely red-hot, and remains so for any length of time. We may easily try the experiment. . .

CAROLINE.

How very curious! The wire is almost white-

hot, and a pungent smell rises from the glass. Pray, how is this accounted for?

MRS. B.

It is owing to a very peculiar property of the vapour of ether, and indeed of many other combustible gaseous bodies. At a certain temperature lower than that of ignition, these vapours undergo a slow and imperfect combustion, which does not give rise, in any sensible degree, to the phenomena of light and flame, and yet extricates a quantity of caloric sufficient to re-act upon the wire and make it red-hot; and the wire in its turn keeps up the effect as long as the emission of vapour continues.

This singular effect, which is also produced by alcohol, may be rendered more striking, and kept up for an indefinite length of time, by rolling a few coils of platina wire, of the diameter of from about 1-60th to 1-70th of an inch, round the wick of a spirit-lamp. If this lamp be lighted for a moment, and blown out again, the wire, after ceasing for an instant to be luminous, becomes red-hot again, though the lamp be extinguished, and remains glowing vividly till the whole of the spirit contained in the lamp has been evaporated and consumed in this peculiar manner.

CAROLINE.

That is extremely curious. But why should not an iron or silver wire produce the same effect?

MRS. B.

Because both iron and silver being much better conductors of heat than platina, the heat is carried off too fast by the two metals to allow the accumulation of caloric necessary to produce the effect in question.

Ether is so light, that it evaporates at the common temperature of the atmosphere; it is therefore necessary to keep it confined by a well-ground glass stopper. No degree of cold known has ever frozen pure alcohol or ether.

CAROLINE.

Is not ether often taken medicinally?

MRS. B.

Yes; it is one of the most effectual antispasmodic medicines, and the quickness of its effects, as such, probably depends on its being instantly converted into vapour by the heat of the stomach through the intervention of which it acts on the nervous system. But the frequent use of ether, like that of spirituous liquors, becomes prejudicial; and, if taken to excess, it produces effects similar to those of intoxication.

We may now take our leave of the vinous fermentation, of which I hope you have acquired a clear idea; as well as of the several products derived from it.

CAROLINE.

Though this process appears, at first sight, so

complicated, it may, I think, be summed up in a few words, as it consists in the conversion of sugar and fermentable bodies into alcohol and carbonic acid, which give rise both to the formation of wine and of all kinds of spirituous liquors.

MRS. B.

We shall now proceed to the *acetous fermentation*, which is thus called, because it converts wine into vinegar by the formation of the acetous acid, which is the basis or radical of vinegar.

CAROLINE.

But is not the acidifying principle of the acetous acid the same as that of other acids — oxygen?

MRS. B.

Certainly: and on that account the contact of air is essential to this fermentation, as it affords the necessary supply of oxygen. Vinegar, in order to obtain pure acetous acid from it, must be distilled and rectified by certain processes.

EMILY.

But pray, Mrs. B., is not the acetous acid frequently formed without this fermentation taking place? Is it not, for instance, contained in acid fruits, and in every substance that becomes sour?

MRS. B.

No, not in fruits; you confound it with the citric, the malic, the oxalic, and other vegetable acids, to which living vegetables owe their acidity. But

whenever a vegetable substance turns sour, after it has ceased to live, the acetous acid is developed by means of the acetous fermentation, in which the substance advances a step towards its final decomposition.

Amongst the various instances of acetous fermentation, that of bread is usually classed.

CAROLINE.

But the fermentation of bread is produced by yeast; — how does that effect it?

MRS. B.

It is found by experience that any substance which has already undergone a fermentation, will readily excite it in one that is susceptible of that process. If, for instance, you mix a little vinegar with wine, which is intended to be acidified, it will absorb oxygen more rapidly, and the process be completed much sooner, than if left to ferment spontaneously. Thus yeast, which is a product of the fermentation of beer, is used to excite and accelerate the fermentation of malt, which is to be converted into beer, as well as that of paste, which is to be made into bread.

CAROLINE.

But if bread undergoes the acetous fermentation, why is it not sour?

MRS. B.

It acquires a certain savour which corrects the heavy insipidity of flour, and may be reckoned a

first degree of acidification, for if the process were carried further, the bread would become decidedly acid.

It has, indeed, been lately discovered, that a considerable quantity of alcohol is produced during the baking of bread ; and a manufacture was established in London, in which an ounce of alcohol was said to be procured from the baking of every quartern loaf.

EMILY.

The fermentation of bread seems then to be more nearly allied to the vinous than to the acetous fermentation.

MRS. B.

If the alcohol were formed during the fermentation of the paste, it certainly would ; but it is not yet ascertained whether it results from the fermentation, or is produced during the process of baking. It has, however, been found that bread from which the alcohol has been extracted keeps fresh longer, and is less liable to become sour, than when baked in the ordinary way.

The *putrid fermentation* is the final operation of Nature, and her last step towards reducing organised bodies to their simplest combinations. All vegetables spontaneously undergo this fermentation after death, provided there be a sufficient degree of heat and moisture, together with access of air : for it is well known that dead plants may be preserved by drying, or by the total exclusion of air.

CAROLINE.

But do dead plants undergo the other fermentation previous to this last ; or do they immediately suffer the putrid fermentation ?

MRS. B.

That depends on a variety of circumstances ; such as the degrees of temperature and of moisture, the nature of the plant itself, &c. But if you were carefully to follow and examine the decomposition of plants from their death to their final dissolution, you would generally find a sweetness developed in the seeds, and a spirituous flavour in the fruits (which have undergone the saccharine fermentation), previous to the total disorganisation and separation of the parts.

EMILY.

I have sometimes remarked a kind of spirituous taste in fruits which were over-ripe, especially oranges, and this was just before they became rotten.

MRS. B.

It was then the vinous fermentation which had succeeded the saccharine : and had you watched these changes attentively, you would probably have found the spirituous taste followed by acidity, previous to the fruit passing to the state of putrefaction.

When the leaves fall from the trees in autumn, they do not (if there is no great moisture in the atmosphere) immediately undergo a decomposition,

but are first dried and withered ; as soon, however, as the rain sets in, fermentation commences, their gaseous products are imperceptibly evolved into the atmosphere, and their fixed remains mixed with their kindred earth.

Wood, when exposed to moisture, also undergoes the putrid fermentation, and becomes rotten.

EMILY.

But I have heard that the *dry rot*, which is so liable to destroy the beams of houses, is prevented by a current of air ; and yet you said that air was essential to the putrid fermentation ?

MRS. B.

True ; but it must not be in such a proportion to the moisture as to dissolve the latter ; and this is generally the case when the rotting of wood is prevented or stopped by the free access of air. The disease commonly called *dry rot*, however, is not a process of putrefaction. It is supposed to depend on a peculiar kind of vegetation, which, by feeding on the wood, gradually destroys it.

EMILY.

And would it not be possible to destroy this vegetation, or prevent its being developed ?

MRS. B.

It has been attempted by steeping timber in the solution of muriate of mercury, commonly called corrosive sublimate. This substance has the property of combining with albumen, and

forming with it an insoluble compound; and as the incipient vegetation which constitutes dry rot consists chiefly of albumen, it was supposed that by this process it might be totally destroyed. Several vessels, as well as public edifices, have been built of timber prepared in this manner, and the expectations of the author of this interesting discovery appear likely to be realised; but time alone can prove their complete success.

Straw and all other kinds of vegetable matter undergo the putrid fermentation more rapidly when mixed with animal matter. Much heat is evolved during this process, and a variety of volatile products are disengaged,—as carbonic acid and hydrogen gas, the latter of which is frequently either sulphuretted or phosphoretted. When all these gases have been evolved, the fixed products, consisting of carbon, small quantities of salts, potash, &c., form a kind of vegetable earth, which makes very fine manure, as it is composed of those elements which form the immediate materials of plants.

CAROLINE.

Pray are not vegetables sometimes preserved from decomposition by petrification? I have seen very curious specimens of petrified vegetables; in which state they perfectly preserve their form and organisation, though in appearance they are transformed to stone.

MRS. B.

That is a kind of metamorphosis, which, now

that you are tolerably well versed in the history of mineral and vegetable substances, I leave to your judgment to explain. Do you imagine that vegetables can be converted into stone?

EMILY.

No, certainly; but they might, perhaps, be changed to a substance in appearance resembling stone.

MRS. B.

It is not so, however, with the substances that are called petrified vegetables; for these are really stone, and generally of the hardest kind, consisting chiefly of silex. The case is this: — When a vegetable is buried under water, or in wet earth, it is slowly and gradually decomposed. As each successive particle of the vegetable is destroyed, its place is supplied by a particle of siliceous earth, conveyed thither by the water. In the course of time the vegetable is entirely destroyed, but the silex has completely replaced it, having assumed its form and apparent texture, as if the vegetable itself were changed to stone.

CAROLINE.

That is very curious! and I suppose that petrified animal substances are of the same nature?

MRS. B.

Precisely. It is equally impossible for either animal or vegetable substances to be transformed to stone. They may be reduced, as we find they

are, by decomposition, to their constituent elements, but cannot be changed to elements which do not enter into their composition.

There are, however, circumstances which frequently prevent the regular and final decomposition of vegetables; as, for instance, when they are buried either in the sea or in the earth, where they cannot undergo the putrid fermentation for want of air. In these cases they are subject to a peculiar change, by which they are converted into a new class of compounds, called *bitumens*.

CAROLINE.

These are substances I never heard of before.

MRS. B.

You will find, however, that some of them are very familiar to you. Bitumens are vegetables so far decomposed as to retain no organic appearance; but their origin is easily detected by their oily nature, their combustibility, the products of their analysis, and the impressions of the forms of leaves, grains, fibres of wood, and even of animals, which they frequently bear.

They are sometimes of an oily liquid consistence, as the substance called *naphtha*, in which we preserve potassium: this is a fine, transparent, colourless fluid, which exudes from clays in some parts of Persia. But more frequently bitumens are solid; as *asphaltum*, a smooth, hard, brittle substance, which easily melts, and forms, in its liquid state,

a beautiful dark brown colour for oil painting. *Jet*, which is of a still harder texture, is a peculiar bitumen, susceptible of so fine a polish that it is used for many ornamental purposes.

Coal is also a bituminous substance, to the composition of which both the mineral and animal kingdoms seem to concur. This most useful mineral appears to consist chiefly of vegetable matter, mixed with the remains of marine animals and marine salts, and occasionally containing a quantity of sulphuret of iron, commonly called pyrites.

EMILY.

It is, I suppose, the earthy, the metallic, and the saline parts of coals which compose the cinders or fixed products of their combustion; whilst the hydrogen and carbon which they derive from vegetables, constitute their volatile products.

MRS. B.

Succin, or *yellow amber*, is a bitumen which the ancients called *electrum*; from whence the word electricity is derived, as that substance is peculiarly, and was once supposed to be exclusively, electric. It is found either deeply buried in the bowels of the earth, or floating on the sea, and is considered as a resinous body which has been acted on by sulphuric acid; its analysis showing that it consists of an oil and an acid. The oil is called *oil of amber*; the acid, the *succinic*.

EMILY.

That oil I have sometimes used in painting, as

it is reckoned to change less than the other kinds of oils.

MRS. B.

The last class of vegetable substances which have changed their nature are *fossil-wood*, *peat*, and *turf*. These are composed of wood and roots of shrubs, which are partly decomposed by being exposed to moisture under ground, and yet, in some measure, preserve their form and organic appearance. The peat or black earth of the moors retains but few vestiges of the roots to which it owes its richness and combustibility; these substances being in the course of time reduced to the state of vegetable earth. But in turf the roots of plants are still discernible, and it equally answers the purpose of fuel. This combustible is used by the poor in heathy countries, which supply it abundantly.

It is too late this morning to enter upon the history of vegetation. We shall reserve the subject, therefore, for our next interview, when I expect that it will furnish us with ample matter for another conversation.

CONVERSATION XXI.

HISTORY OF VEGETATION.

MRS. B.

THE VEGETABLE KINGDOM may be considered as the link which unites the mineral and animal creation into one common chain of being; for it is through the means of vegetation alone that mineral substances are introduced into the animal system; since, generally speaking, it is from vegetables that all animals ultimately derive their sustenance.

CAROLINE.

I do not understand that: the human species subsists as much on animal as on vegetable food; and there are some carnivorous animals which will eat only animal food.

MRS. B.

That is true; but you do not consider that those which live on animal food derive their sustenance equally, though not so immediately, from vegetables. The meat which we eat is formed from the herbs of the field; and the prey of carnivorous animals proceeds, either directly or indirectly,

from the same source. It is, therefore, through this channel that the simple elements become a part of the animal frame. We should in vain attempt to derive nourishment from carbon, hydrogen, and oxygen, either in their separate state, or combined in the mineral kingdom; for it is only by being united in the form of vegetable combination that they become capable of conveying nourishment.

EMILY.

Vegetation, then, seems to be the method which Nature employs to prepare the food of animals.

MRS. B.

That is certainly its principal object. The vegetable creation does not exhibit more wisdom in that admirable system of organisation, by which it is enabled to answer its own immediate ends of preservation, nutrition, and propagation, than in its grand and ultimate object of forming those arrangements and combinations of principles which are so well adapted for the nourishment of animals.

EMILY.

But I am very curious to know whence vegetables obtain those principles which form their immediate materials?

MRS. B.

This is a point on which we are yet so much in the dark, that I cannot hope fully to satisfy your curiosity, but what little I know on this subject I will endeavour to explain to you.

CAROLINE.

Pray tell us at least in what manner manure is favourable to vegetation ?

MRS. B.

Organic manure consists of all kinds of organic substances, which have undergone decomposition, and are thereby reduced very nearly to their elementary state. Now I ask you what is the use of supplying the soil with such substances ?

CAROLINE.

It is, I suppose, in order to furnish vegetables with the elements which enter into their composition ; for manures not only contain oxygen, hydrogen, carbon, and nitrogen, but by decomposition supply the soil with these elements.

EMILY.

But how is it that animal is preferred to vegetable manure ? It appears to me that the decomposition of vegetables would be better adapted to the formation of new plants.

MRS. B.

It is owing to the greater quantity of nitrogen that exists in animal matter. The chemical affinities of nitrogen being weaker than those of any other body, it must necessarily yield up the elements with which it is combined as soon as it comes in contact with other bodies, consequently the presence of nitrogen in compounds is favour-

able to decomposition, and therefore it makes the best manure.

Mr. Liebig is of opinion that the putrid fermentation is owing to the facility with which nitrogen parts with its oxygen.

EMILY.

But, Mrs. B., since all organised bodies are in the common course of nature reduced by decomposition to their elementary principles, they must necessarily in that state enrich the soil, and afford food for plants. How is it, then, that agriculture, which cannot increase the quantity of these elements, increases so prodigiously the produce of the earth?

MRS. B.

It is by suffering none of these decaying bodies to be dispersed and wasted; by studying their properties in order to apply them to the soil with the greatest advantage; by a due preparation of the soil, either for the general purposes of vegetation, or for that of the particular crop which is to be sown. Thus, if it be too wet, it may be drained; if too loose and sandy, it may be rendered more consistent and retentive of water by the addition of clay or loam; if too poor, it may be enriched by calcareous earths. On soils thus improved, manures, if judiciously chosen, will act with peculiar efficacy; and if attention be paid to spread them on the ground at a proper season;

to mix them thoroughly with the soil; to destroy the weeds which might appropriate those nutritive principles to their own use; to remove the stones which would impede the growth of the plant, we may obtain a produce very much more abundant than the land would otherwise afford. A rational system of agriculture, therefore, consists in supplying plants with such things as they want, and in so cultivating the soil as to remove all mechanical or chemical obstruction to their growth. The best mode of discovering what is the most appropriate nourishment for plants is to analyse them; and as this belongs exclusively to chemistry, I shall enlarge a little more upon it.

CAROLINE.

But I think the soil should be analysed as well as the crops, Mrs. B., in order to know whether it contains proper food for them, and teach us what should be added to it and what subtracted from it.

MRS. B.

Certainly; plants derive their nourishment from two sources, the earth and the atmosphere. We shall first examine that which they obtain from the soil.

In the chemical analysis of plants, they yield oxygen, hydrogen, and carbon, and also a small quantity of nitrogen, the latter being contained chiefly in the seeds. Mineral or inorganic substances, such as salts and alkaline earths, are

also found in plants, and appear to be necessary to the sustenance of vegetable life, and these they obtain wholly from the soil.

EMILY.

But, Mrs. B., hyacinths grow and blossom luxuriantly in water, without any soil.

MRS. B.

Plants which can be reared in water will blossom, but ripen no fruit; that is to say, their seed is incapable of reproducing the species. In the analysis of such plants no more mineral or inorganic matter is found than was contained in the seed from which they sprung; while plants which are grown in earth yield a considerable proportion of mineral substances, such as sulphates, muriates, nitrates, and phosphates of alkaline or earthy bases.

These ingredients can be obtained only from the soil; they vary not only in different species of the same vegetable, but in different parts of the same plant. The phosphates and salts of potash, for instance, are always found in the grains of corn, and it is well known that corn cannot be cultivated in a soil which contains none of these salts.

EMILY.

Do these saline bodies form a constituent part of the soil, or do they result from the decomposition of manure?

MRS. B.

Both the one and the other. Soil was originally formed from the decomposition of rocks and other stony bodies, which are buried in the earth far beneath the surface of the ground. These in the course of time and by the action of air and water crumble to pieces, laying the foundation of a soil. In mountainous countries, many rocks appear externally jutting out above the surface, where being completely exposed to the action of air and water, they are gradually torn down, or worn away, and their fragments sent to form soil in the valley below, being either dashed to pieces in their fall from crag to crag, or crumbled to atoms as they are washed down the steep declivity. All these rocks consist of various compounds of earthy and alkaline substances, which ultimately form a constituent part of the soil, and thence find their way into the vegetable system through the roots; and when the plants in the course of nature perish, these salts are returned to the soil by the decomposition of vegetable manure. You see, therefore, that plants may get saline bodies either from the primitive soil, or from manure: the latter is the readiest mode; but should it prove insufficient, these salts may be obtained from the original rock. Hence the use of subsoil ploughing, which brings the soil resulting from the crumbled rock sufficiently near the surface, for the saline materials to be absorbed by the roots of plants.

When these saline bodies exist in manure, they are washed out by the rain during the decomposition, are dissolved, and ready to be absorbed by plants. Or they may be obtained from the ashes of plants, for not being of a combustible nature, they remain unaltered in the ashes of plants which have been burnt. It is this which constitutes the great value of wood ashes used as manure.

The mechanical use of the soil is to support the plant firmly, so as to prevent the wind from injuring it. By its open porous texture a good soil enables the roots of plants to extend in all directions, and at the same time affords innumerable channels through which food is conveyed to their roots.

CAROLINE.

Does this food enter into the spongioles of plants in their state of simple bodies or in that of manure?

MRS. B.

It cannot enter into the roots either in a solid or a gaseous form, for the spongioles are said to absorb only liquids; but the fermentation which manure undergoes in the soil, reduces it to substances much less compound than that in which they existed in organic manure. The affinity of the elementary bodies for each other is so strong that it is very difficult to obtain them isolated; for decomposition no sooner takes place than they reunite, but always under a more simple form,

such for instance, as water, formed by the combination of oxygen and hydrogen; carbonic acid, resulting from the union of oxygen and carbon; and ammonia, produced by the combination of nitrogen and hydrogen.

CAROLINE.

How much preparation manure requires to render it fit to be absorbed by the roots of plants! it is actually cooking their food.

MRS. B.

We are far from having yet completed all that is required for their repast. The decomposition of organic matter takes place very slowly, and before it is reduced to its simplest state of combination, it forms a solid brown substance called *Humus*, which abounds in vegetable soils, giving them a dark brown colour.

EMILY.

Then I think there must be a great deal of humus in the rich vegetable mould of our kitchen garden.

MRS. B.

Yes; *vegetable mould* consists of original soil formed from the crumbling of rocks, mixed up with the remains of animal and vegetable matter; it is, in a word, earth in which humus is decomposed.

CAROLINE.

This must prove excellent food for plants;

humus being derived from the decomposition of organised bodies, is ready to enter again the living organic system.

MRS. B.

Not quite ; for humus being a solid body, cannot enter into the roots of plants.

CAROLINE.

It is something like portable soup, I suppose, which requires to be melted and diluted before it can be eaten.

MRS. B.

Humus, however, is not soluble in water, but when exposed in a moist state to the air, it attracts oxygen, and gives out an equal volume of carbonic acid gas.

EMILY.

Which means, no doubt, that the oxygen of the air unites with the carbon of the humus, and produces carbonic acid ?

MRS. B.

Precisely so ; if the experiment be carefully made in the laboratory, and the carbonic acid be removed in proportion as it is formed, and fresh air admitted, the same action continues until the humus is completely destroyed.

CAROLINE.

Destroyed ! then how can it nourish plants ?

MRS. B.

When I used the expression destroyed, I did

not mean annihilated; that you know is impossible. All I intended to say was, that the humus had entered into a new combination, and formed another body.

CAROLINE.

Oh yes; it is converted into carbonic acid by its union with the oxygen of the air.

EMILY.

But, if the spongioles of plants can absorb only liquids, carbonic acid gas cannot obtain admittance there any more than humus in a solid state?

MRS. B.

That is true; but humus, consisting of the decomposition of organic matter generally, contains also oxygen and hydrogen, and these two simple bodies combine and form water, as soon as the carbon is withdrawn from them.

CAROLINE.

Oh, pray let me finish the sentence, or rather complete the process, Mrs. B. This water absorbs the carbonic acid, and thus all the ingredients of humus are brought together again, forming not a gas, nor a solid body, but a liquid, in which state alone they can be absorbed by the roots of plants.

MRS. B.

You are quite right.

EMILY.

Then, is all the humus of our gardens and fields

converted into carbonic acid and water to feed the plants we raise in them?

MRS. B.

Yes ; both garden mould and arable land are, you know, constantly turned up by the spade, the hoe, or the plough, and a fresh surface of soil exposed to the action of the air, so that the fertilising powers of the humus are fully developed.

CAROLINE.

I thought that the purpose of hoeing, raking, ploughing, and all such agricultural operations, was to break the clods of earth, so as to render the soil light, and enable the soft roots of young plants to penetrate it.

MRS. B.

Those are mechanical advantages of great importance also, especially if you consider that this lightness of soil opens a number of channels, through which both air and water find their way to the roots of plants.

EMILY.

There is one thing I cannot understand. In natural forests the soil is never turned up so as to bring the humus to the surface, and expose it to the action of the air : how then can it be converted into carbonic acid and water fit for the nourishment of these trees?

MRS. B.

The materials of which humus is formed consist

of dead leaves, decayed branches, and rotten trunks of trees: these fall upon the surface of the ground, and if sometimes carried lower down by rain, are still sufficiently superficial to be more or less under the influence of the atmosphere. In natural vegetation the plant restores to the soil all the sustenance it has drawn from it.

EMILY.

Then why are soils newly brought into cultivation so rich and fertile, if there has been no accumulation of vegetable nourishment in them?

MRS. B.

They do accumulate a small quantity of carbon, but their great fertility arises from their never having been exhausted of the materials they naturally possess. Observe the difference between natural vegetation and that produced by culture. When a crop of corn comes to maturity, instead of remaining on the ground to decay, and fertilise the soil for the following year, it is cut down and carried away to be eaten by animals.

CAROLINE.

But if agriculture robs the soil of its produce, it makes amends by supplying it with manure.

MRS. B.

You see, therefore, that when we force the soil to yield an artificial crop, we must use artificial means of restoring the elements we have withdrawn from it, otherwise its fertility would annu-

ally decrease, and in the course of time would be exhausted.

CAROLINE.

Yet, Mrs. B., we every year cut down crops of grass and carry them away to feed our cattle, so that there can remain but little vegetable matter to be converted into humus, and how that humus is to come in contact with the air to be changed into carbonic acid I cannot imagine; for the roots of grass are so thickly matted together, and the surface of the ground is so stiff, that it seems impossible for the air to get to it.

MRS. B.

Well then, if the air cannot get to the soil, we must bring the soil to the air.

CAROLINE.

But you cannot plough up meadows without destroying the grass?

MRS. B.

Our ploughs no doubt would, but nature is provided with ploughs of so delicate a structure that they will turn up just as much soil as is required without injury to the grass.

CAROLINE.

I cannot conceive what you mean?

MRS. B.

Have you never observed that in wet weather the grass of lawns and meadows is often covered

with worm casts? What are these?—small portions of earth brought up from the lower parts of the soil by worms, and deposited on the surface, where they are in immediate contact with the atmosphere.

CAROLINE.

Oh, the dear little Lilliputian ploughmen! I had no idea they could be so useful, as it appears they are.

MRS. B.

These worms feed on earth from which they extract some vegetable nourishment but not sufficient for their sustenance; they therefore work their way up to the surface of the ground in search of dead leaves; there they deposit the earth contained in their bodies, and lightened of this load, they drag back the dead leaves they meet with. They are thus rewarded for their labour by carrying back a plentiful store of food. Then these journeys of the worms backwards and forwards have another advantage, — they perforate the hardened soil of grass-land, and render it accessible both to air and to water.

EMILY.

Yes, every little wriggling worm which works its way up to the surface, must form a channel through which both air and rain can freely pass into the soil; yet the quantity of earth they bring up, and the humus contained in it, must be very small.

MRS. B.

It is sufficient for the vegetation of grass, so far as relates to the soil; but plants, as I have told you, derive nourishment also from another source, to which it is time that we should turn our attention; this is the *atmosphere*.

The leaves are the organs by means of which plants absorb nutriment from the air. They are full of pores, called *stomates*, which perform the office of mouths. Those on the upper surface of the leaf exhale the superfluous moisture of the plant; those on the under surface imbibe carbonic acid from the atmosphere, retain the carbon, and restore the oxygen to the air.

CAROLINE.

How very strange that plants should feed on air! especially when they are full grown, and require, one would think, more solid nourishment.

MRS. B.

Carbon, you should recollect, exists equally in a solid and in a gaseous state; and though the leaves absorb it in the latter form (dissolved in water), they convert it into a solid body: the hardest and heaviest part of a tree,—wood, consists almost wholly of carbon; all the calcareous earths are carbonates, and in a crystallised form pure carbon, you know, is a diamond.

CAROLINE.

Then what a prodigious quantity of carbon, in

a gaseous state, the leaves must absorb, to make the wood of a large oak !

MRS. B.

Think, also, of the millions of mouths which are constantly sucking it in. The leaves of a large tree, if spread on the ground, might perhaps cover an acre of land : yet when forming the foliage of the tree, they offer the same extent of surface to the action of the air, contained in a comparatively small volume. I do not think it would be possible to conceive any other form, which would present so great a surface included in so small a compass.

EMILY.

There is so much beauty in the foliage of a tree,—so much graceful variety of form,—such richness and delicacy of colour,—that one might imagine it was intended merely to please the eye ; but it has a far higher destination, and is wonderfully adapted to the performance of its absorbent functions.

MRS. B.

Use does not preclude beauty ; and we are surrounded with proofs that the bounteous Author of Nature has deigned to render what was created for our use, at the same time grateful to our senses.

CAROLINE.

Oh, then, if the grass of meadows can get carbon from the air, it does not require so much humus as I had supposed.

MRS. B.

Nitrogen is also copiously absorbed from the atmosphere; hence the abundance of this element to be found in grasses, corn, and a great variety of other plants.

EMILY.

Oxygen seems to be the only part of the atmosphere which is not absorbed by plants.

MRS. B.

Oxygen is also absorbed, but under circumstances which I cannot yet explain to you.

The celebrated Mr. Liebig, to whom we owe the greater part of what is new in the vegetable economy, is of opinion that plants not only feed on the atmosphere, but that it serves as a vehicle to convey to them other materials necessary to their healthful vegetation. Thus, he says, that plants derive through this means the greater part, if not the whole, of the ammonia they contain. Ammonia, he observes, being one of the products of the decay and putrefaction of animal matter, is evolved into the atmosphere, wherever such decomposition occurs. Large quantities of it are thus daily emitted; rain dissolves it, brings it down to the ground, and buries it in the soil, whence it is absorbed by the roots of plants. In proof of this, ammonia is known to exist both in snow and rain water, as well as in many mineral springs, and it has also been discovered in the roots of plants.

EMILY.

Then, ammonia merely rises into the atmosphere and descends again, without undergoing any change? It is certainly rather a circuitous way of reaching the roots of plants.

CAROLINE.

It rises into the air to seek for water, which will both dissolve it and convey it to the roots of plants.

MRS. B.

You are quite right, excepting in seeming to attribute intelligence to ammonia, while it simply follows the law of nature. Rain follows the same course; it evaporates into the air, where it forms clouds, and thence descends in rain; but, observe, it rises pure water, and in its return it brings with it whatever it is capable of dissolving, such as ammonia, carbonic acid, and so on.

EMILY.

No wonder that rain should be so beneficial to vegetation, for it not only furnishes plants with a supply of its own constituents, oxygen and hydrogen, but it conveys other materials to the roots of plants. But I thought that rain was perfectly pure water?

MRS. B.

It contains neither earth nor saline matters, and the proportion of ammonia, or carbon, it may hold in solution is too small, compared to the mass of liquid, to produce any sensible effect on the purity

of the water. Now, observe the advantage which agriculturists may derive from a knowledge of the two sources whence plants obtain nourishment. They will argue thus : — “ When we cut down a crop of corn we must replace all the nourishment it has received from the soil, else the soil will in a very few years be exhausted : but we need not trouble ourselves to renew the materials which the crop has received from the atmosphere, as that bountiful store is ever ready to yield it to plants gratuitously.”

CAROLINE.

And then, Mrs. B., they might add, — “ It is more important to renew the saline bodies than carbon and ammonia ; for if there be a deficiency of these latter elements in the soil, they may be obtained from the atmosphere, whilst, if the salts are wanting, the crop cannot procure them elsewhere.”

MRS. B.

Since agriculture has been exalted to the rank of a science, the prevailing opinion is, that the chief use of manure is to restore to the soil those inorganic substances we take away from it every harvest ; such as the phosphates, nitrates, and salts of potash. Experiments are daily made to test the truth of this theory, and bone dust, wood ashes, salts of potash, in a word, whatever substance contains these inorganic bodies, have been used as manure, and found considerably to in-

crease the fertility of the soil : and so eagerly are such compounds now sought after by agriculturists, that they spread soda and saltpetre over their corn fields, and have even begun to make use of the refuse of the coal-gas works for the same purpose.

CAROLINE.

Then I dare say that guano, which has been so much talked of, is of this description.

MRS. B.

Not exactly, for it is organic manure ; but it is among those which give out ammonia most readily and in the largest proportions, and which consequently have the greatest influence on vegetation. Guano consists of the droppings of sea fowl ; it has lately been imported in large quantities from Ichaboe and Peru.

EMILY.

But, Mrs. B., I cannot understand how a plant begins to grow, for it can absorb neither from the earth nor from the air, until its roots and its leaves are developed.

MRS. B.

True ; the plant, when it first germinates, is nourished by the contents of the seed : this excellent milk gives the young nursling strength to shoot out roots into the soil, from whence it then absorbs the whole of its nourishment until its leaves are developed. It afterwards receives little

more than saline matters from that source, and derives its chief nutriment by absorption from the atmosphere.

But during the whole of its existence a plant never ceases to absorb water from the soil, and to part with its superabundant moisture by the upper surface of the leaves, whilst the lower surface is as constantly employed in imbibing gases from the atmosphere.

EMILY.

But if the atmosphere goes on from year to year feeding vegetation, may not its nutritive powers at length be exhausted?

MRS. B.

There is no such danger. Nature is provided with immense resources for carrying on the formation of organised life, with which you will become better acquainted when we treat of animal chemistry; and when these are all brought into activity, they replenish the various systems through which they pass, so as to prevent exhaustion in any of them. Thus, the atmosphere contributes to the sustenance of organised bodies, which in their turn supply the soil with nutritive elements; these again re-enter the system of animated nature, and during every change, as well as every period of stationary existence, whether living or dead, organised nature is continually evolving into the atmosphere some portion of its being. In the interior of the earth, that immense labora-

tory which is incessantly carrying on the most stupendous chemical processes, the same results take place. Volcanos disgorge vast stores of primitive bodies: hot springs, earthquakes, and other apparently casual and irregular incidents of nature, contribute to the same end; for every created being, whether mineral, vegetable, or animal, has its appointed part to play in this grand scene of action, for the promotion of general good.

But to return to the leaves: important as are the functions we have seen them perform, they contribute in a still more essential manner to the vegetable economy. Leaves may be considered as so many Lilliputian laboratories, in which all that is destined by Nature to become food for plants is submitted to a regular chemical process, in which it is converted into vegetable substances; there is nothing whatever, either simple or compound, which can form any part of a plant, without having previously undergone this preparation: for the rising sap consists of a mixture of crude ingredients totally unfit for that purpose.

CAROLINE.

Then where can the buds of trees find food in the spring, before the leaves are developed?

MRS. B.

Nature has arranged an admirable provision for this purpose. In the autumn, after the fruit has ripened, annual plants perish; they are either cut

down like grass or corn, or they die a natural death.

EMILY.

That is the case in the flower garden : the blossom falls, the leaves wither, and the plant dies.

MRS. B.

But it is not so with trees and shrubs ; their leaves continue in vigour, performing their several functions, long after the fruit has ripened and been gathered.

CAROLINE.

And for what purpose ? for it seems useless to prepare food for a plant which, if it does not die, falls into a state of torpor during the winter, and requires no nourishment.

MRS. B.

This apparently unnecessary vegetation of trees is for the very purpose of preparing food for the buds the following spring. In the autumn, after the fruit has ripened, the leaves cease to form woody fibre, &c., and the materials they used for that purpose, are now employed in the production of a nutritive substance, well known to you under the name of *starch*. After being elaborated in the leaves it is stored up in the stem of the plant, where the spring sap finds it as it rises, dissolves it, and conveys it to the buds.

CAROLINE.

How admirable this is ! If one ventures to find

fault with any thing in Nature, the explanation shows that it is a perfection instead of a deficiency. Then both the buds and the young plants germinating from seed, are fed by the same substance. How little did I think that starch, which I considered as of use only to the washerwoman, should perform so important a part in vegetation.

MRS. B.

The use of starch in washing is one of its lowest offices: it is of greater importance in the arts, and when we come to trace its career in the animal system, your admiration will be raised still higher; but that is not our business at present. Observe that the starch lodged in the seeds of plants must have been elaborated in the leaves during the spring or summer, in order to be safely deposited in the seed before the harvest is got in, or that the annual dies a natural death.

EMILY.

Certainly; else the grain would not be able to germinate. The existence of annuals not extending beyond one season, the whole course of their vegetation must be carried on in that short period.

MRS. B.

Both buds and seeds require an ample store of provision in the spring, in order to be enabled to perform their respective tasks; hence the additional source of spring sap destined for that particular purpose.

EMILY.

The provision of starch in the stems reminds me of having eaten some oranges in Italy of two years' growth. After ripening the first year they became shrivelled during the winter, the juice acquiring the consistence of jelly. This was melted by the rising sap the following spring, so that the oranges were enriched by the nourishment of two years, and their flavour was delicious.

MRS. B.

There is considerable analogy between the two cases. The pine and several other trees of the same description contain so much starch in their stems, that in Sweden, where these trees abound, bread has been made from their bark in seasons of great scarcity.

There are many different varieties of starch, adapted to the different seeds they are intended to nourish. Common starch exists in great quantities in the grain of corn, especially in wheat; it abounds also in potatoes. When grated potatoes are placed on a sieve, under a stream of cold water, a large quantity of starch may be washed out, which will settle at the bottom of the water, as starch is very little soluble in cold water.

CAROLINE.

But we know that it is in hot water, Mrs. B., else it would not be used in washing.

MRS. B.

The starch which is lodged in the stems of trees in autumn undergoes another chemical process in the leaves in the spring, by which it produces sugar and gum, two very important materials of plants.

EMILY.

Starch, sugar, and gum, then, seem to be the proper food for plants germinating from seeds, or buds shooting from the branch ; and carbonic acid and ammonia, when they are in a state of maturity.

MRS. B.

Yes ; but though starch is peculiarly suited to the nourishment of vegetables, it affords very little to animals.

EMILY.

I wonder at that, for we obtain more sustenance from wheat than from any other vegetable food I know of ; and you said that it abounded in starch.

MRS. B.

There are other materials combined with starch in the grain of corn, such as gluten, sugar, and gum : and it is these, rather than the starch, which render bread so nourishing to man.

CAROLINE.

Besides, you know, Emily, that starch was not intended for our food, but for that of plants, and if we choose to eat the seeds instead of allowing them to germinate, we have no right to complain of starch not being nutritive.

MRS. B.

I am inclined to think that Nature intended grain for the food of animals as well as for the reproduction of its own species, for the provision is far greater than is necessary for the latter purpose. Then it is animals and not vegetables who enjoy the existence of these seeds, and though pure starch yields but little nourishment to man, that which we derive from bread proves that it does not interfere with the nutritive qualities of the other substances with which it is combined in the seed.

Plants vary not only in their form and structure according to the family or species to which they belong, but the same plant will vary according to the different kinds of food with which it is supplied; and the quality and quantity of the vegetable substances elaborated in the leaves will depend on these circumstances. Thus a superabundance of carbon unaccompanied by nitrogen cannot be converted into gluten, albumen, or wood: it will form sugar, oil, wax, resin, or gum. On the other hand, an excess of food containing nitrogen will increase the production of gluten, albumen, and mucilage. The quantity of starch in potatoes is known to increase when the soil contains much humus; and to decrease when it is strongly manured. In the first case they have a mealy, in the second a waxy consistency.

Certain classes of plants are found to require

peculiar substances for their development. Thus wheat, as I have told you, must have alkalies and phosphates. Leguminous plants, on the contrary, contain none of these substances, and many of them thrive on lime and salts. Some plants require minute quantities of sulphate of iron, while others cannot vegetate in a soil which contains any considerable quantity of that salt. It is the same with regard to water. One plant flourishes best in a dry soil; it suits another to have a great deal of moisture at one period of its growth, and drought at another.

In a wise system of cultivation, therefore, the rule should be to furnish each plant with those substances which are necessary for its perfect growth, and to withdraw those which it does not want, in order to reserve them for such plants as require them.

EMILY.

This is no doubt the reason why the same crops are not cultivated on the same spot during several successive years, for they would exhaust the soil of the substances they especially required, and leave those which did not suit them untouched.

MRS. B.

You are quite right; a judicious rotation of crops, each of which requires different salts and alkaline substances, is a much more advantageous system of cropping. Farmers learn this by ex-

perience. But all these improvements in agriculture are not so easily accomplished as you would imagine. For instance, the simple addition of the substance in which the plant is deficient does not always succeed, and you are obliged to pursue a circuitous path to attain your end. Let us suppose, for example, that you found by analysis that a field of corn was deficient in carbon, what course would you take to furnish it with that substance!

EMILY.

I should lay a quantity of manure containing carbonic acid on the land.

MRS. B.

And this would be of no avail, for in the natural course of vegetation a crop of corn fully exposed to the air cannot be deficient in carbonic acid, unless it is by a sickly state incapable of absorbing it; and this hypothesis is confirmed by experience, for if you give plants so circumstanced neutral salts or alkaline earths, they will soon acquire the carbon in which they were deficient.

CAROLINE.

That is very curious! Then, when a plant wants one thing you must give it another to enable it to procure the first. These saline bodies then are rather medicine than food to the plant?

MRS. B.

It is true that mineral substances afford a plant the means of obtaining nourishment rather

than of furnishing it themselves, but in what manner we cannot tell.

CAROLINE.

Oh! well, I think that I can. I dare say they act as stimulants to the stomates of the leaves and of the spongioles, to suck in food from the air and the soil.

EMILY.

Or perhaps they may relax these stomates so as to enable them to absorb a greater quantity of food.

MRS. B.

So little is known with respect to the action of these bodies on each other, that I believe you may settle it according to your own fancy, until we are better informed on the subject. But observe that the application of salts and alkalies can be made by means of the soil only. Now it is often out of our power to change the character of the soil, and in that case our only resource is to change that of the crop which is to be raised on it, and select one which will have the best chance of thriving in the soil such as it is, or such as we have it in our power to make it.

CAROLINE.

And the analysis of plants will tell us that at once, you know, Mrs. B.

MRS. B.

There are more obstacles to impede the pro-

gress of agriculture than you are aware of. Its fundamental principles are not yet fully established, but the work is begun, and as both philosophers and practical men are fully sensible of its importance, this most useful of all arts will I trust henceforth be treated in the scientific manner which it deserves.

EMILY.

All you have told us, Mrs. B., respecting vegetation, and the means of improving it by agriculture, is very wonderful and very beautiful. But though experience daily proves the advantage of a knowledge of this art, there is still a difficulty which I cannot get over. A certain quantity of elementary principles exists in nature, which it is not in the power of man either to augment or diminish. Of these principles you have taught us that both the animal and vegetable creation are composed. Now the more of them is taken up by the vegetable kingdom, the less, it would seem, will remain for animals: and, therefore, the more populous the earth becomes, the less vegetation it will produce.

MRS. B.

Your reasoning is very plausible: but experience every where contradicts the inference you would draw from it; since we find that the animal and vegetable kingdoms, instead of thriving, as you would suppose, at each other's expense, always

increase and multiply together. For you should recollect that animals can derive the elements of which they are formed only through the medium of vegetables. And you must allow that your conclusion would be valid only if every particle of the several principles which could possibly be spared from other purposes were employed in the animal and vegetable creations. Now we have reason to believe that a much greater proportion of these principles than is required for such purposes remains either in an elementary state, or engaged in a less useful mode of combination in the mineral kingdom. Possessed of such immense resources as the atmosphere and the waters afford us for oxygen, hydrogen, carbon, and nitrogen, so far from being in danger of working up all our simple materials, we cannot suppose that we shall ever bring agriculture to such a degree of perfection as to require the whole of what these resources could supply.

Nature, however, in thus furnishing us with an inexhaustible stock of raw materials, leaves it to the ingenuity of man to apply them in the most appropriate manner; and, like a kind parent, stimulates him to exertion by setting the example and pointing out the way: for it is on the operations of nature that all the improvements of art are founded. I hope that you are now convinced that we shall not easily experience

a deficiency of nutritive elements to fertilise the earth ; and that, provided we are but industrious in applying them to the best advantage, by improving the art of agriculture, no limits can be assigned to the fruits which we may expect to reap from our labours.

CONVERSATION XXII.

HISTORY OF VEGETATION.

CAROLINE.

I AM very much pleased, Mrs. B., with all you have told us about agriculture; and I can assure you that I feel much more interested in its progress and improvement than before I knew any thing about it.

EMILY.

I have frequently thought that the culture of the land was not considered as a concern of sufficient importance. Manufactures always take the lead: and health and innocence are frequently sacrificed to the prospect of a more profitable employment. It has often grieved me to see poor manufacturers crowded together in close rooms, and confined for the whole day to the most uniform and sedentary employment, instead of being engaged in that innocent and salutary kind of labour, which Nature seems to have assigned to man for the immediate acquirement of comfort, and for the preservation of his existence. I am sure that you agree with me in thinking so, Mrs. B.

MRS. B.

I am entirely of your opinion, my dear, in regard to the importance of agriculture; the more especially as the comforts and conveniences of life, which we are all enjoying, are also derived from the soil; but as these latter require the aid of manufactures to fit them for our use, I am far from wishing to depreciate such important sources of enjoyment. Besides, as the labour of one man is sufficient to produce food for several, those whose industry is not required in tillage must do something in return for the food which others provide for them. They exchange, consequently, the accommodations for the necessaries of life. Thus, the carpenter and the weaver lodge and clothe the peasant, who supplies them with their daily bread. The greater the stock of provisions, therefore, which the husbandman produces; the greater is the quantity of accommodation which the artificer prepares. Such are the happy effects which naturally result from civilised society. It would be wiser, therefore, to endeavour to improve the situation of those who are engaged in manufactures, than to indulge in vain declamations on the hardships to which they are too frequently exposed.

But we must not yet take our leave of the subject of agriculture; we have prepared the soil,—it remains for us now to sow the seed. In this operation we must be careful not to bury it too

deep in the ground, as the access of air is absolutely necessary to its germination; the earth must, therefore, lie loosely and lightly over it, in order that the air may penetrate. Hence, as I have shown you, the use of ploughing, digging, harrowing, and raking, &c. A certain degree of heat and moisture, such as usually takes place in the spring, is likewise necessary.

CAROLINE.

One would imagine you were going to describe the decomposition of an old plant, rather than the formation of a new one: for you have enumerated all the requisites of fermentation.

MRS. B.

Do you forget, my dear, that the young plant derives its existence from the destruction of the seed, and that it is actually by the saccharine fermentation that the latter is decomposed.

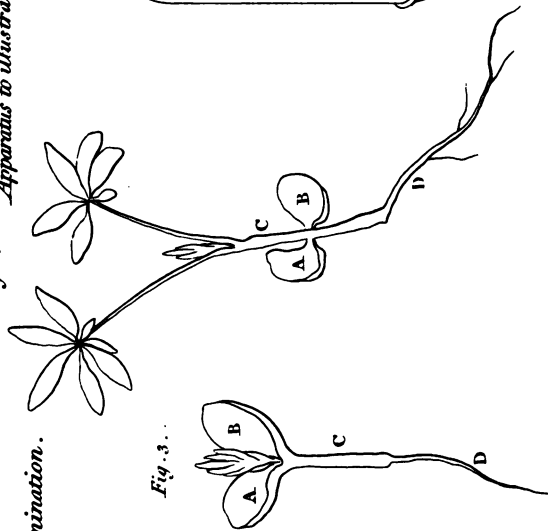
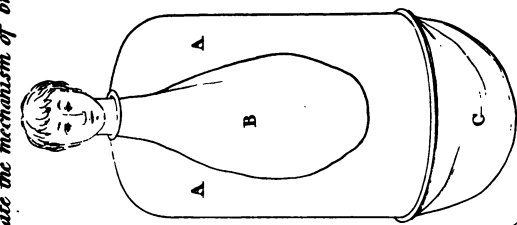
CAROLINE.

True; I wonder that I did not recollect that. The temperature and moisture required for the germination of the seed is, then, employed in producing the saccharine fermentation within it?

MRS. B.

Certainly. But, in order to understand the nature of germination, you should be acquainted with the different parts of which the seed is composed. The external covering or envelope con-

Fig. 4. Apparatus to illustrate the mechanism of breathing.



Germination.

Fig. 1.



Fig. 2.



Fig. 3.

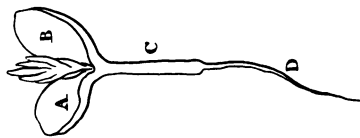


Fig. 1. A. B. C. D. Envelope. D. Radicle. Fig. 2. A. B. C. D. Radicle. Fig. 3. A. B. C. D. Radicle. Fig. 4. A. B. C. D. Radicle. Fig. 5. A. B. C. D. Radicle. Fig. 6. A. B. C. D. Radicle.

Drawn by the Author.

Published by Longmans & Co. Paternoster Row

Engraved by Leary.

tains, besides the germ of the future plant, the substance which is to constitute its first nourishment: this substance, which is called the *parenchyma*, consists of starch, gum, and oil, as we formerly observed.

The seed is generally divided into two compartments, called *lobes* or *cotyledons*, as is exemplified by this bean. (Plate XVIII. fig. 1.) The dark-coloured kind of string which divides the lobes is called the *radicle*, as it forms the root of the plant; and it is from a contiguous substance, called *plumula*, which is enclosed within the lobes, that the stem arises. The figure and size of the seed depend very much upon the cotyledons. Some have only one, as wheat, oats, barley, and all the grasses; but most seeds of temperate climates have two cotyledons. When the seed is buried in the earth, at any temperature above 40 degrees, it imbibes water, which softens and swells the lobes; it then absorbs oxygen, which combines with some of its carbon, and is returned in the form of carbonic acid. This loss of carbon increases the comparative proportion of hydrogen and oxygen in the seed, and excites the saccharine fermentation, by which the parenchymatous matter is converted into a kind of sweet emulsion. In this form it is carried into the radicle by vessels appropriated to that purpose; and in the mean time, the fermentation having caused the seed to burst, the cotyledons are rent asunder, the radicle strikes

into the ground and becomes the root of the plant; and hence the fermented liquid is conveyed to the plumula, whose vessels have been previously distended by the heat of the fermentation. The plumula being thus swelled, as it were, by the emulsive fluid, raises itself, and springs up to the surface of the earth, bearing with it the cotyledons, which as soon as they come in contact with the air, spread themselves, and are transformed into leaves. If we go into the garden, we shall probably find some seeds in the state which I have described.

EMILY.

Here are some lupines which are just making their appearance above ground.

MRS. B.

Let us take up several of them to observe their different degrees of progress in vegetation. Here is one which has but recently burst its envelope; do you see the little radicle striking downwards? (Plate XVIII. fig. 2.) In this the plumula is not yet visible. But here is another in a greater state of forwardness; the plumula, or stem has risen out of the ground, and the cotyledons are split asunder and converted into seed-leaves; so called from their resemblance to common leaves, though they have no real claim to that name, as they do not perform the same functions. (Plate XVIII. fig. 3.)

CAROLINE.

These seed-leaves are very thick and clumsy, and quite unlike the other leaves, which I perceive are just beginning to appear.

MRS. B.

It is because they retain the remains of the parenchyma, with which they still continue to nourish the young plant, as its roots have not yet sufficient strength to provide sustenance from the soil. But in this third lupine (Plate XVIII. fig. 4.) the radicle has sunk deep into the earth, and sent out several shoots, each of which is furnished with a mouth to suck up nourishment from the soil: the function of the seed-leaves, therefore, being no longer required, they are gradually decaying; and the plumula is become a regular stem, shooting out small branches, and spreading its foliage.

EMILY.

There seems to be a very striking analogy between a seed and an egg: both require an elevation of temperature to be brought to life; both at first supply with aliment the organised being which they have produced; and as soon as this has attained sufficient strength to procure its own nourishment the egg-shell breaks, whilst in the plant the seed-leaves fall off.

MRS. B.

There is certainly some resemblance between these processes; and, when you become acquainted

with animal chemistry, you will frequently be struck with its analogy to that of the vegetable kingdom.

As soon as the young plant feeds from the soil, it requires the assistance of leaves; these, you know, are the organs by which it absorbs gases from the atmosphere, and throws off its superabundant fluid: this last secretion is much more plentiful in the vegetable than in the animal creation; and the great extent of surface of the foliage of plants is admirably calculated for carrying it on in sufficient quantities. This transpired fluid consists of little more than water.

EMILY.

Vegetation, then, must be essentially injured by destroying the leaves of the plant. I wonder it does not kill a tree to deprive it of its leaves, and yet this is regularly done with mulberry trees to feed silk worms.

MRS. B.

It would very seriously injure the tree, if the sap which is necessarily accumulated in the stem and branches, did not soon force out new foliage. Leaves are sometimes destroyed by caterpillars or by blights; but from whatever cause this happens, it not only diminishes the transpiration, but also the absorption by the roots; for the quantity of sap absorbed is always in proportion to the quantity of fluid thrown off by transpiration. *You, see, therefore, the necessity that a young*

plant should unfold its leaves as soon as it begins to derive its nourishment from the soil; and, accordingly, you will find that those lupines which have dropt their seed-leaves, and are no longer fed by the parenchyma, have spread their foliage, which performs the offices just described.

This function of transpiration, you may recollect, is confined to the upper surface of the leaves; whilst, on the contrary, the lower surface, which is more rough and uneven, and furnished with a kind of hair or down, is destined to absorb those gases which the plant derives from the atmosphere.

As soon as a young plant makes its appearance above ground, light, as well as air, becomes necessary to its preservation. Light is essential to the development of the colours, and to the general thriving of the plant. You may have often observed what a predilection vegetables have for light. If you make any plants grow in a room, they all spread their leaves, and extend their branches, towards the windows.

CAROLINE.

And many plants close up their flowers as soon as it is dark. But may not this be owing to the cold and dampness of the evening air?

MRS. B.

That does not appear to be the case; for in a course of curious experiments, made by Mr. Sennebier, of Geneva, on certain plants which he reared

by lamplight, he found that the flowers closed their petals whenever the lamps were extinguished.

We must now examine the effect of water on plants ; it is the basis not only of the sap, but of all the vegetable juices. Water is the vehicle which carries into the plant the various salts and other ingredients required for the formation and support of the vegetable system. Nor is this all ; part of the water itself is decomposed by the organs of the plant ; the hydrogen becomes a constituent part of oil, of extract, of colouring matter, &c., whilst a portion of the oxygen enters into the formation of gum, of starch, of sugar, and of vegetable acids. But the greater part of the oxygen, proceeding from the decomposition of the water, is converted into a gaseous state by the caloric disengaged from the hydrogen during its condensation in the formation of the vegetable materials. In this state the oxygen is transpired by the leaves of plants when exposed to the sun's rays. Thus you find, that the decomposition of water by the organs of the plant is not only a means of supplying it with its chief ingredient, hydrogen, but at the same time of replenishing the atmosphere with oxygen, — a principle which requires continual renovation, to make up for the great consumption of it occasioned by the numerous oxygenations, combustions, and respirations, which are constantly taking place on the surface of the globe.

EMILY.

What a striking instance of the harmony of nature !

MRS. B.

And how admirable the design of Providence, who makes every different part of the creation thus contribute to the support and renovation of each other !

But the intercourse of the vegetable and animal kingdoms, through the medium of the atmosphere, extends still farther. Animals, in breathing, not only consume the oxygen of the air, but load it with carbonic acid, which, if accumulated in the atmosphere, would, in the course of time, render it unfit for respiration. Here the vegetable kingdom again interferes : it attracts and decomposes the carbonic acid, retains the carbon for its own purposes, and returns the oxygen for ours.

CAROLINE.

How interesting this is ! I do not know a more beautiful illustration of the wisdom which is displayed in the laws of nature.

MRS. B.

Faint and imperfect as are the ideas which our limited perceptions enable us to form of Divine Wisdom, still they cannot fail to inspire us with awe and admiration. What, then, would be our feelings, were the complete system of nature at once displayed before us ! So magnificent a scene

would, probably, be too great for our limited and imperfect comprehension; and it is no doubt among the wise dispensations of Providence, to veil the splendour of a glory with which we should be overpowered. But it is well suited to the nature of a rational being to explore, step by step, the works of the creation, to endeavour to connect them into harmonious systems, and, in a word, to trace, in the chain of beings, the kindred ties and that benevolent design which unite its various links, and secure its preservation.

CAROLINE.

But of what nature are the organs of plants which are endued with such wonderful powers?

MRS. B.

They are so minute, that their structure, as well as the mode in which they perform their functions, generally elude our examination: we may consider them as so many vessels or apparatus, contained chiefly in the leaves, and appropriated to perform, with the assistance of the principle of life, certain chemical processes, by means of which these vegetable compounds are generated. We may, however, trace the tannin, resins, gum, mucilage, and some other vegetable materials, in the organised arrangement of plants, in which they form the bark, the wood, the leaves, flowers, and seeds.

The *bark* is composed of three coats, the *epidermis*, the *parenchyma*, and the *cortical layers*.

The epidermis is the external covering of the plant. It is a thin, transparent membrane, consisting of a number of slender fibres, crossing each other, and forming a kind of network. When of a white glossy nature, as in several species of trees, in the stems of corn and of reeds, it is composed of a thin coating of silica, which accounts for the strength and hardness of those long and slender stems. Sir H. Davy was led to the discovery of the siliceous nature of the epidermis of such plants, by observing the singular phenomenon of sparks of fire emitted by the collision of ratan canes, with which two boys were fighting in a dark room. On analysing the epidermis of the cane, he found it to be almost entirely siliceous.

CAROLINE.

With iron, then, a cane, I suppose, will strike fire very easily !

MRS. R.

Certainly. There is a very pretty experiment, which is so simple that you may perform it yourselves. It consists in dissolving a little silicate of potash in water, and putting a piece of packthread in it. After it is well soaked, lay the packthread between two pieces of blotting-paper; moisten it with a little solution of tartaric acid; and when dry the string will become quite rigid. In evergreens the epidermis is resinous, and, in some few plants, is coated with wax. The resin, from its want of affinity for water, tends to pre-

serve the plant from the destructive effects of violent rains, severe climates, or inclement seasons, to which this species of vegetables is peculiarly exposed.

EMILY.

Resin must preserve wood just like a varnish, as it is the essential ingredient of varnishes.

MRS. B.

Yes; and by this means it prevents, likewise, all unnecessary expenditure of moisture.

The parenchyma is situated immediately beneath the epidermis: it is that green rind which appears when you strip a branch of any tree or shrub of its external coat of bark. The parenchyma is not confined to the stem or branches, but extends over every part of the plant. It forms the green matter of the leaves, and is composed of tubes, filled with a peculiar juice.

The cortical layers are immediately in contact with the wood; they abound with tannin and gallic acid, and consist of small vessels, through which the sap descends after being elaborated in the leaves.

EMILY.

And through what vessels does the sap ascend?

MRS. B.

That function is performed by the alburnum, or wood, which is immediately beneath the cortical layers. The wood is composed of woody fibre,

mucilage, and resin. The fibres are disposed in two ways; some of them longitudinally, and these form what is called the silver grain of the wood; the others, which are concentric, are distinguished by the name of the spurious grain. These latter are disposed in layers, from the number of which the age of the tree may be computed, a new one being produced annually. The oldest, and, consequently, most internal part of the alburnum is called heart-wood; it appears to be dead, at least no vital functions are discernible in it. It is through the living alburnum that the sap rises. But in the spring, when the plant requires an unusual quantity of sap, for the purpose of nourishing the buds, another source, I have already told you, springs up, passing through the centre of the stem, and thence through the concentric layers of wood into the buds.

This spring sap is laden with a rich store of starch, which it meets with in the cells of the wood, and conveys straight to the buds.

EMILY.

Then the spring sap feeds the buds without passing through the leaves?

MRS. B.

No; every thing which the plant assimilates or makes a part of itself, must have been previously elaborated in the leaves; the starch you may

recollect underwent that operation the preceding autumn.

The common sap which rises through the alburnum spreads into the leaves, where it is transformed into the peculiar juices from which the plant more immediately derives its nourishment. These juices are very conspicuous, as the vessels which contain them are much larger than those through which the sap circulates. The peculiar juices of plants differ much in their nature, not only in different species of vegetables, but frequently in different parts of the same individual plant; they are sometimes saccharine, as in the sugar-cane; sometimes resinous, as in firs and evergreens; sometimes of a milky appearance, as in the laurel and the fig-tree.

EMILY.

I have often observed, that in breaking a young shoot, or in bruising a leaf of laurel, a milky juice will ooze out in great abundance.

MRS. B.

And it is by making incisions in the bark that pitch, tar, and turpentine are obtained from fir-trees. The durability of this species of wood is chiefly owing to the resinous nature of its peculiar juices. The volatile oils have, in a great measure, the same preservative effects, as they defend the parts with which they are connected from the attacks of insects. This tribe seems to have as great

an aversion to perfumes as the human species take delight in them. They scarcely ever attack any odoriferous parts of plants; and it is not uncommon to see every leaf of a tree destroyed by a blight, whilst the blossoms remain untouched.

Cedar, sandal, and all aromatic woods are, on this account, of great durability.

EMILY.

But the wood of the oak, which is so much esteemed for its durability, has, I believe, no smell. Does it derive this quality from its hardness alone?

MRS. B.

Not entirely; for the chestnut, though considerably harder and firmer than the oak, is not so lasting. The durability of the oak is, I believe, in a great measure owing to its having very little heartwood, the alburnum preserving its vital functions longer than in other trees.

CAROLINE.

If incisions are made into the alburnum and cortical layers, may not the ascending and descending sap be procured in the same manner as the peculiar juice is from the vessels of the parenchyma?

MRS. B.

Yes; but, in order to obtain specimens of these fluids in any quantity, the experiment must be made in the spring, when the sap circulates with

the greatest energy. For this purpose a small bent glass tube should be introduced into the incision, through which the sap may flow, without mixing with any of the other juices of the tree. From the wood the sap will flow much more plentifully than from the bark, as the ascending sap is more liquid, more abundant, and more rapid in its motion than that which descends; for the latter, having been deprived by the operation of the leaves of a considerable part of its moisture, contains a greater proportion of solid matter, which retards its motion. But the most abundant flow of sap is to be obtained by perforating to the centre of the stem, where the spring sap rises, and from whence it will flow with greatest velocity.

The last of the organs of plants is the *flower*, or *blossom*, which produces the *fruit* and *seed*. These may be considered as the ultimate purpose of nature in the vegetable creation. From fruit and seed animals derive both a plentiful source of immediate nourishment, and an ample provision for the reproduction of the same means of subsistence.

The seed, which forms the final product of mature plants, we have already examined, as constituting the first rudiments of future vegetation.

These are the principal organs of vegetation, by means of which the several chemical processes, which are carried on during the life of the plant, are performed.

EMILY.

But how are the various principles, which enter into the composition of vegetables, so combined by the organs of the plant as to be converted into vegetable matter?

MRS. B.

By chemical processes, certainly; but I have already told you that the apparatus in which they are performed is so extremely minute as completely to elude our examination. We can form an opinion, therefore, only by the result of these operations. The sap is evidently composed of water, absorbed by the roots, and holding in solution the various principles which it derives from the soil. From the roots the sap ascends through the alburnum into the stem, and thence branches out to every extremity of the plant. And after being elaborated in the leaves, it is poured into the vessels which convey the descending sap, and in its progress through the plant, from the leaves to the roots, deposits, in the several sets of vessels with which it communicates, the materials on which the growth and nourishment of each plant depend. It is thus that the various peculiar juices, saccharine, oily, mucous, acid, and colouring, are formed; as also the more solid parts, starch, woody fibre, tannin, resins, concrete salts; in a word, all the immediate materials of vegetables, as well as the organised parts of plants; which latter, besides the power of secreting these

from the sap for the general purpose of the plant, have also that of applying them to their own particular nourishment. Whatever remains after all these processes of vegetation are completed is said to exude into the soil.

CAROLINE.

Then, when the sap reaches the leaves it must meet with the food absorbed from the atmosphere? I hope it is an amicable meeting?

MRS. B.

We may conclude that it is, since they combine to supply the wants of the plant.

EMILY.

They do not all combine, Mrs. B., for you know some of them are evaporated by the leaves.

MRS. B.

That is true. Together with the sap circulates a certain quantity of carbonic acid, which is gradually disengaged from the plant by its internal heat.

CAROLINE.

What! have vegetables a peculiar heat analogous to animal heat?

MRS. B.

No; but both wood and bark being bad conductors of caloric, the interior of the stem of a tree receives less heat in summer, and parts with less in winter, than unorganised bodies; in con-

sequence of which, vegetable heat is above that of unorganised bodies in winter, and below them in summer. The wood of a tree in its interior is about sixty degrees, when the thermometer is at seventy or eighty in the air. And the bark, though so much exposed, is seldom below forty in winter.

EMILY.

But why should the process of vegetation take place only at one season of the year, whilst a total inaction prevails during the other?

MRS. B.

Heat is such an important chemical agent, that its effect might, perhaps, alone account for the impulse which the spring gives to vegetation. In order to explain the mechanism of that operation, it has been supposed that the warmth of the spring dilates the vessels of plants, and produces a kind of vacuum, into which the sap (which had remained in a state of inaction in the trunk during the winter, under the form of starch) begins to rise: this is followed by the ascent of the sap contained in the roots; and room is thus made for fresh sap, which the roots in their turn pump up from the soil. This process goes on till the plant blossoms and bears fruit, which terminates its summer career; but, when the cold weather sets in, the fibres and vessels contract, the leaves wither, and are no longer able to per-

form their offices of transpiration and of absorption, and, as these secretions stop, the roots cease to absorb sap from the soil. If the plant be an annual, its life then terminates; if not, it remains in a state of torpid inaction during the winter; or the only internal motion which takes place is that of a small quantity of resinous juice, which slowly rises from the stem into the branches, and enlarges their buds during the winter.

CAROLINE.

Yet, in evergreens, vegetation must continue throughout the year.

MRS. B.

True; but it goes on in a very imperfect manner, compared to the vegetation of spring and summer.

We have dwelt much longer on the history of vegetable chemistry than I had intended; but we have at length, I think, brought the subject to a termination.

CAROLINE.

I rather wonder that you did not reserve the account of the fermentations for the conclusion; for the decomposition of vegetables naturally follows their death, and can hardly, it seems, be introduced with so much propriety at any other period.

MRS. B.

It is difficult to determine at what precise point

it may be most eligible to enter on the history of vegetation ; every part of the subject is so closely connected, and forms such an uninterrupted chain, that it is by no means easy to divide it. Had I begun with the germination of the seed, which, at first view, seems to be the most proper arrangement, I could not have explained the nature and fermentation of the seed, or have described the changes which manure must undergo, in order to yield the vegetable elements. To understand the nature of germination, it is necessary, I think, previously to decompose the parent plant, in order to become acquainted with the materials required for that purpose. I hope, therefore, that, upon further consideration, you will find that the order which I have adopted, though apparently less correct, is, in fact, the best calculated for the elucidation of the subject.

It is supposed by many naturalists, that electricity exerts very considerable influence on vegetation, and as it is known to play an important part throughout the system of nature, we are led to infer, that the vegetable economy may be more or less affected by it ; but no satisfactory results having been deduced from the experiments made to ascertain this point, it still remains hypothetical.

Mr. Faraday has been long engaged in important experiments on those mysterious agents, *heat, light, magnetism*, and electricity, with the view of discovering whether they are distinct

elements, or whether they are not varied results of one and the same principle. In the hands of so distinguished a philosopher, we may hope that the relation of these bodies to each other, if not their actual identity, may be verified, and that a more perfect knowledge of them will bring them more perfectly under our control.

CONVERSATION XXIII.

ON THE COMPOSITION OF ANIMALS.

MRS. B.

WE are now come to the last branch of chemistry, which comprehends the most complicated order of compound beings. This is the animal creation; the history of which cannot but excite the highest degree of curiosity and interest, though we often fail in attempting to explain the laws by which it is governed.

EMILY.

But, since all animals ultimately derive their nourishment from vegetables, the chemistry of this order of beings must consist merely in the conversion of vegetable into animal matter.

MRS. B.

Very true; but the manner in which this is effected is, in a great measure, concealed from our observation. This process is called *animalisation*, and is performed by peculiar organs. The difference of the animal and vegetable kingdoms does not, however, depend merely on a different arrangement of combinations, but on a different

proportion of the elements of which they are formed.

CAROLINE.

But animal compounds must contain the same elements as vegetables, though they may vary in their proportions and their combinations.

MRS. B.

Certainly; they both consist of oxygen, hydrogen, carbon, and nitrogen, but nitrogen is much more abundant in the animal than in the vegetable kingdom; animal substances contain, also, a greater and more constant proportion of phosphoric acid and other saline matters. From these elements are formed the immediate materials of animals, which are *gelatine*, *albumen*, and *fibrine*.

EMILY.

Are those all? I am surprised that animals should be composed of fewer kinds of materials than vegetables; for they appear much more complicated in their organisation.

MRS. B.

Their organisation is certainly more perfect and intricate, and the ingredients which occasionally enter into their composition are more numerous. But notwithstanding the wonderful variety observable in the texture of the animal organs, we find that the original compounds, from which all the varieties of animal matter are derived, may be

reduced to the heads just mentioned. Animal substances, being the most complicated of all natural compounds, are most easily susceptible of decomposition, as the scale of attraction increases in proportion to the number of constituent principles. Their analysis is, however, both difficult and imperfect; for as they cannot be examined in their living state, and are liable to alteration immediately after death, it is probable that, when submitted to the investigation of a chemist, they are always more or less altered in their combinations and properties from what they were whilst they made part of the living animal.

EMILY.

The mere diminution of temperature which they experience by the privation of animal heat must, I should suppose, be sufficient to derange the order of attractions that existed during life.

MRS. B.

That is one of the causes, no doubt; but there are many other circumstances which prevent us from studying the nature of living animal substances. We must, therefore, in a considerable degree, confine our researches to the phenomena of these compounds in their inanimate state.

These three kinds of animal matter, gelatine, albumen, and fibrine, form the basis of all the various parts of the animal system; either solid, as

the *skin, flesh, nerves, membranes, cartilages, and bones* ; or fluid, as *blood, chyle, milk, mucus, the gastric, and pancreatic juices, bile, perspiration, saliva, tears, &c.*

CAROLINE.

Is it not surprising that so great a variety of substances, and so different in their nature, should all arise from so few materials, and from the same original elements ?

MRS. B.

The difference in the nature of various bodies depends, as I have often observed to you, rather on their state of combination than on the materials of which they are composed. Thus, in considering the chemical nature of the creation in a general point of view, we observe that it is throughout composed of a very small number of elements ; but, when we divide it into the three kingdoms, we find that in the mineral the combinations seem to result from the union of elements either mechanically or chemically brought together ; whilst in the vegetable and animal kingdoms the attractions are peculiarly and regularly produced by appropriate organs, whose action depends on the vital principle ; and we may farther observe, that by means of certain spontaneous changes and decompositions, the elements of one kind of matter become subservient to the reproduction of another ; so that the three kingdoms are intimately con-

nected, and constantly contributing to the preservation of each other.

EMILY.

There is, however, one very considerable class of elements which seems to be confined to the mineral kingdom, — I mean the metals.

MRS. B.

Not entirely : they are found, though in minute quantities, both in the vegetable and animal kingdoms.

Let us now proceed to examine the nature of the three principal materials of the animal system.

Gelatine or *jelly* is the chief ingredient of skin, and of all the membranous parts of animals. It may be obtained from these substances, by means of boiling water, under the forms of glue, size, isinglass, and transparent jelly.

CAROLINE.

But these are of a very different nature ; they cannot, therefore, be all pure gelatine.

MRS. B.

Not entirely, but very nearly so. Glue is extracted from the skin of animals. Size is obtained either from skin in its natural state, or from leather. Isinglass is gelatine procured from a particular species of fish : it is, you know, of this substance that the finest jelly is made ; and this is done by merely dissolving the isinglass in boiling water,

and allowing the solution to congeal. The wine, lemon, and spices, are added, only to flavour the jelly.

CAROLINE.

But jelly is often made of hartshorn shavings, and of calves' feet: do these substances contain gelatine?

MRS. B.

Yes. Gelatine may be obtained from almost any animal substance, as it enters more or less into the composition of them all. The process for obtaining it is extremely simple, as it consists merely in boiling the substance which contains it with water. The gelatine dissolves in water; and may be obtained of any degree of consistence or strength, by evaporating this solution. Bones, in particular, produce it very plentifully, as they consist of phosphate of lime combined or cemented by gelatine. Horns, which are a species of bone, will yield abundance of gelatine. The horns of the hart are reckoned to produce gelatine of the finest quality; they are reduced to the state of shavings, in order that the jelly may be more easily extracted by the water. It is of hartshorn shavings that the jellies for invalids are usually made, as they are of very easy digestion.

CAROLINE.

It appears singular that hartshorn, which yields such a powerful ingredient as ammonia, should at

the same time produce so mild and insipid a substance as jelly.

MRS. B.

And it will increase your surprise to hear that it is from the gelatine of bones that ammonia is produced. You must observe, however, that the processes by which these two substances are obtained from bones are very different. By the simple action of water and heat the gelatine is separated; but in order to procure the ammonia, or what is commonly called hartshorn, the bones must be distilled, by which means the gelatine is decomposed, and hydrogen and nitrogen combined in the form of ammonia. So that the first operation is a mere separation of ingredients, whilst the second requires a chemical decomposition.

CAROLINE.

But when jelly is made from hartshorn shavings, what becomes of the phosphate of lime which constitutes the other part of bones?

MRS. B.

It is easily separated by straining. But the jelly is afterwards more perfectly purified, and rendered transparent, by adding white of egg, which being coagulated by heat, rises to the surface along with any impurities.

EMILY.

I wonder that bones are not used by the common people to make a jelly; a great deal of whole-

some nourishment might, I should suppose, be procured from them, though the jelly would perhaps not be quite so good as if made from harts-horn shavings.

MRS. B.

There is a prejudice among the poor against a species of food which is usually thrown to the dogs; and as we cannot expect them to enter into chemical considerations, it is in some degree excusable. Besides, in order to dissolve bones, and obtain the gelatine from them, a prodigious quantity of heat is required. This mode has been occasionally adopted in charitable soup establishments, but it would be too expensive a process for the individual poor.

The solution of bones in water is greatly promoted by an accumulation of heat. This may be effected by means of an extremely strong metallic vessel, called *Papin's Digester*, in which the bones and water are enclosed, without any possibility of the steam making its escape. A heat can thus be applied much superior to that of boiling water; and bones, by this means, are completely reduced to a pulp. But this process still consumes too much fuel to be adapted to the lower classes.

CAROLINE.

And why should not a manufacture be established for grinding or macerating bones, or at least for reducing them to the state of shavings,—

when, I suppose, they would dissolve as readily as hartshorn shavings.

MRS. B.

It would be difficult to collect them clean for such a purpose; but they are used for making hartshorn and sal ammoniac: and such is the superior science and industry of this country, that we now send sal ammoniac to the Levant, though it originally came to us from Egypt. Bones form also, you may recollect, a very valuable manure.

EMILY.

When jelly is made of isinglass, does it leave no sediment?

MRS. B.

No; nor does it even require clarifying, as it consists almost entirely of pure gelatine; any foreign matter which is mixed with it being thrown off during the boiling in the form of scum.—These are processes which you may see performed in great perfection in the culinary laboratory, by that very able and most useful chemist, the cook.

CAROLINE.

To what an immense variety of purposes chemistry is subservient! It appears, in this respect, to have an advantage over most other arts and sciences, which, very often, have a tendency, to confine the imagination to their own particular object; whilst the pursuit of chemistry is so extensive and diversified, that it inspires a general

curiosity, and a desire of inquiring into the nature of every object.

MRS. B.

You will find that to be the case with all the sciences; knowledge, if liberally pursued, can never circumscribe the views, but must always tend to enlarge them.

CAROLINE.

Well, then, to consider the culinary art in a scientific point of view, I suppose that soup is likewise composed of gelatine; for, when cold, it often assumes the consistence of jelly?

MRS. B.

Not entirely; for though soups generally contain a quantity of gelatine, the most essential ingredient is a mucous or extractive matter, a peculiar animal substance, very soluble in water, which has a strong taste, and is more nourishing than gelatine. The various kinds of portable soup consist of this extractive matter in a dry state, which, in order to be made into soup, requires only to be dissolved in water.

Gelatine, in its solid state, is a semiductile transparent substance, without either taste or smell.—When exposed to heat, in contact with air and water, it first swells, then fuses, and finally burns. You may have seen the two first parts of this operation performed in the carpenter's glue-pot.

CAROLINE.

And the third also; for glue is very apt to burn, if not melted with care. But you said that gelatine had no smell; and glue has a very disagreeable one.

MRS. B.

Glue is not pure gelatine: not being designed for eating, it is prepared without attending to the state of the ingredients, which are more or less contaminated by particles that have become putrid.

Gelatine may be precipitated from its solution in water by alcohol. — We shall try this experiment with a glass of warm jelly. You see that the gelatine subsides by the union of the alcohol and the water.

EMILY.

How is it, then, that jelly is flavoured with wine, without producing any precipitation?

MRS. B.

Because the alcohol contained in wine is already combined with water and other ingredients, and is, therefore, not at liberty to act upon the jelly as when in its separate state. Gelatine is soluble both in acids and in alkalies: the former, you know, are frequently used to season jellies.

CAROLINE.

Among the combinations of gelatine we must not forget one which you formerly mentioned, — that with tannin, to form leather.

MRS. B.

True; but you must observe that leather can be produced only by gelatine in a membranous state; for though pure gelatine and tannin will produce a substance chemically similar to leather, yet the texture of the skin is requisite to make it answer the useful purposes of that substance.

The next animal substance we are to examine is *albumen*: this, although constituting a part of most of the animal compounds, is frequently found insulated in the animal system. The white of egg, for instance, consists almost entirely of albumen: the substance which composes the nerves, the serum, or white part of the blood, and the curds of milk, is little else than albumen variously modified.

In its most simple state, albumen appears in the form of a transparent viscous fluid, possessed of no distinct taste or smell: it coagulates at the low temperature of 165 degrees; and when once solidified, it will never return to its fluid state.

Sulphuric acid and alcohol are each of them capable of coagulating albumen in the same manner as heat; as I am going to show you.

EMILY.

Exactly so.—Pray, Mrs. B., what kind of action is there between albumen and silver? I have sometimes observed that if the spoon with which

I eat an egg happens to be wetted, it becomes tarnished.

MRS. B.

It is because the white of egg (and, indeed, albumen in general) contains a little sulphur, which, at the temperature of an egg just boiled, will decompose the drop of water that wets the spoon, and produce sulphuretted hydrogen gas, which has the property of tarnishing silver.

We may now proceed to *fibrine*. — This is an insipid and inodorous substance, having somewhat the appearance of fine white threads adhering together: it is the essential constituent of muscles or flesh, in which it is mixed with and softened by gelatine. It is insoluble both in water and alcohol, but sulphuric acid converts it into a substance very analogous to gelatine.

These are the essential and general ingredients of animal matter; but there are other substances, which, though not peculiar to the animal system, usually enter into its composition; such as oils, acids, salts, &c.

Animal oil is the chief constituent of fat: it is contained in abundance in the cream of milk, whence it is obtained in the form of butter.

EMILY.

Animal oil I think you said was similar in its composition to vegetable oil?

MRS. B.

If not exactly the same, it is at least very analogous, the constituents of both being hydrogen and carbon; but animal oil contains also nitrogen; a principle which seldom enters into the composition of vegetable oils, and never in so large a proportion.

There are a few animal acids, that is to say, acids peculiar to animal matter, from which they are almost exclusively obtained.

The animal acids have triple bases of hydrogen, carbon, and nitrogen. Some of them are found native in animal matter; others are produced during its decomposition.

Those which we find ready formed are, —

The *bombic acid*, which is obtained from silk-worms.

The *formic acid*, from ants.

The *lactic acid*, from the whey of milk.

The *caseic acid*, from casein, which is the pure curd of milk.

The *sebacic*, *margaritic*, and *oleic acids*, from oil or fat.

The *cetic acid*, from spermaceti.

Those formed during the decomposition of animal substances by heat are the *prussic* and *zoonic* acids. This last is produced by the roasting of meat, and gives it a brisk flavour. The class of animal acids is not very extensive, nor are they, generally speaking, of great importance. The

prussic acid is, I think, the only one sufficiently interesting to require any further comment. It can be formed by an artificial process without the presence of any animal matter; and it may likewise be obtained from a variety of vegetables, particularly those of the narcotic kind, such as poppies, laurel, &c. But it is commonly obtained from blood, by strongly heating that substance with caustic potash: the alkali attracts the acid from the blood, and forms with it a *prussiate of potash*. From this state of combination the prussic acid can be obtained pure by means of other substances, which have the power of separating it from the alkali.

EMILY.

But if this acid does not exist ready formed in blood, how can the alkali attract it from thence?

MRS. B.

It is the triple basis only of this acid that exists in the blood: and this is developed and brought to the state of acid during the combustion. The acid, therefore, is first formed, and it afterwards combines with the potash.

EMILY.

Now I understand it. And how can prussic acid be artificially made?

MRS. B.

By passing ammoniacal gas over red-hot char-

coal; and hence we learn that the constituents of this acid are hydrogen, nitrogen, and carbon. The two first are derived from the volatile alkali, the last from the combustion of the charcoal.*

CAROLINE.

But this does not accord with the system of oxygen being the principle of acidity.

MRS. B.

The colouring matter of Prussian blue is called an acid, because it unites with alkalies and metals, and not from any other characteristic properties of acids: perhaps the name is not strictly appropriate. Besides, you must recollect that, since the discovery of chlorine and iodine, chemists no longer consider oxygen as the exclusive generator of acids. Sir H. Davy, I have already informed you, was led by his experiments on dry acids to suspect that water might be essential to acidity. And it is the opinion of some chemists, that acidity may possibly depend rather on the arrangement than on the presence of any particular principles. But we have not yet done with the prussic acid. It has a strong affinity for metallic oxides, and precipitates the solutions

* The basis of prussic acid has been ascertained by M. Gay-Lussac to be a combination of nitrogen and carbon, which he has called *cyanogen*. This compound, when combined with hydrogen, forms prussic acid, or, as it is now called, *hydrocyanic acid*. Pure cyanogen, in the state of gas, may be obtained from prussiate of mercury by distillation.

of iron in acids of a blue colour. This is the Prussian blue, or prussiate of iron, so much used in the arts, and with which I think you must be acquainted.

EMILY.

Yes, I am ; it is used in painting, both in oil and in water colours ; but it is not reckoned a permanent oil colour.

MRS. B.

That defect arises, I believe, from its being badly prepared, which is the case when the iron is not so fully oxidated as to form a red oxide. For a solution of green oxide of iron (in which the metal is more slightly oxidated) makes only a pale green, or even a white precipitate, with prussiate of potash ; and this gradually changes to blue by being exposed to the air, as I can immediately show you.

CAROLINE.

It already begins to assume a pale blue colour. But how does the air produce this change ?

MRS. B.

By oxidating the iron more perfectly. If we pour some nitrous acid on it, the blue colour will be immediately produced, as the acid will yield its oxygen to the precipitate, and fully saturate it with this principle, as I will show you.

CAROLINE.

It is very curious to see a colour change so instantaneously.

MRS. B.

Hence you perceive that Prussian blue cannot be a permanent colour unless prepared with red oxide of iron; since by exposure to the atmosphere it gradually darkens, and in a short time is no longer in harmony with the other colours of the painting.

CAROLINE.

But it can never become darker, by exposure to the atmosphere, than the true Prussian blue, in which the oxide is perfectly saturated?

MRS. B.

Certainly not. But in painting, the artist, not reckoning upon partial alterations in his colours, gives his blue tints that particular shade which harmonises with the rest of the picture. If, afterwards, those tints become darker, the harmony of the colouring must necessarily be destroyed.

CAROLINE.

Pray of what nature is the paint called *carmine*?

MRS. B.

It is an animal colour prepared from *cochineal*, an insect, the infusion of which produces a very beautiful red.

CAROLINE.

Whilst we are on the subject of colours, I should like to learn of what *ivory black* consists?

MRS. B.

It is a carbonaceous substance obtained by the combustion of ivory. A more common species of black is obtained from the burning of bone.

CAROLINE.

But during the combustion of ivory or bone, the carbon, I should have imagined, must be converted into carbonic acid gas, instead of this black substance.

MRS. B.

In this, as in most combustions, a considerable part of the carbon is simply volatilised by the heat, and again obtained concrete on cooling. This colour, therefore, may be called the soot produced by the burning of ivory or bone.

CONVERSATION XXIV.

ON THE ANIMAL ECONOMY.

MRS. B.

WE have now acquired some idea of the various materials which compose the animal system ; but if you are curious to know in what manner these substances are formed by the animal organs, from vegetable as well as from animal substances, it will be necessary to have some previous knowledge of the nature and functions of these organs, without which it is impossible to form any distinct idea of the processes of *animalisation* and *nutrition*.

CAROLINE.

I do not exactly understand the meaning of the word *animalisation*.

MRS. B.

Animalisation is the process by which the food is *assimilated*, that is to say, converted into animal matter ; and *nutrition* is that, by which the food, thus assimilated, is rendered subservient to the purposes of nourishing and maintaining the animal system.

CAROLINE.

This, I am sure, must be the most interesting of

all the branches of chemistry ; particularly as I expect that we shall hear something of the nature of respiration, and of the circulation of the blood.

MRS. B.

These functions undoubtedly occupy a most important place in the history of the animal economy. —But I must previously give you a short account of the principal organs by which the various operations of the animal system are performed. These are—

The *Bones*,
 Muscles,
 Blood vessels,
 Lymphatic vessels,
 Glands, and
 Nerves.

The *bones* are the most solid part of the animal frame : they constitute the support of its various parts, and in a great measure determine its form and dimensions.

EMILY.

The bones of animals correspond with the wood of vegetables ; but you told us that they were not made of carbon, but of phosphate of lime, cemented by gelatine.

MRS. B.

During the earliest period of animal life, they consist almost entirely of gelatinous membranes, having the form of the bones, but of a loose spongy texture, somewhat resembling a honey-comb, the

cells or cavities of which are destined to be filled with phosphate of lime : it is the gradual acquisition of this salt which gives to the bones their subsequent hardness and durability. Infants first receive it from their mother's milk, and afterwards derive it from all animal and from most vegetable food, especially farinaceous substances (such as wheat flour), which contain it in sensible quantities. A portion of the phosphate, after the bones of the infant have been sufficiently expanded and solidified, is deposited in the teeth, which consist at first only of a gelatinous membrane, or case, fitted for the reception of this salt ; and which, after acquiring hardness within the gum, gradually protrude from it.

CAROLINE.

How very curious this is ! and how ingeniously nature has first provided for the solidification of such bones as are immediately wanted, and afterwards for the formation of the teeth, which would not only be useless, but detrimental in infancy !

MRS. B.

In quadrupeds the phosphate of lime is deposited likewise in their horns, and the hair or wool with which they are generally clothed.

In birds it serves also to harden the beaks and the quills of their feathers.

When animals are arrived at a state of maturity, and their bones have acquired a sufficient degree

of solidity, the phosphate of lime which is taken with the food is seldom assimilated, excepting when the female nourishes her young; when it is all secreted into the milk, as a provision for the tender bones of the nursling.

EMILY.

So that whatever becomes superfluous to one being, is immediately wanted by another; and the child acquires strength precisely by the species of nourishment which is no longer necessary to the mother. Nature is, indeed, an admirable economist.

CAROLINE.

Pray, Mrs. B., does not the disease in the bones of children, called the rickets, proceed from a deficiency of phosphate of lime?

MRS. B.

I have heard that this disease may arise from two causes; it is sometimes occasioned by the growth of the muscles being too rapid in proportion to that of the bones. In this case the weight of the flesh is greater than the bones can support, and presses upon them so as to produce a swelling of the joints, which is the great indication of the rickets. The other cause of this disorder is supposed to be an imperfect digestion and assimilation of the food, attended with an excess of acid, which counteracts the formation of phosphate of lime. In both instances, therefore, care should

be taken to alter the child's diet, not merely by increasing the quantity of aliment containing phosphate of lime, but also by avoiding all food that is apt to turn acid on the stomach, and to produce indigestion. But the best preservative against complaints of this kind is, no doubt, good nursing: when a child has plenty of air and exercise, the digestion and assimilation will be properly performed, no acid will be produced to interrupt these functions, and the muscles and bones will grow together in due proportion.

CAROLINE.

I have often heard the rickets attributed to bad nursing, but I never could have guessed what connection there was between exercise and the formation of the bones.

MRS. B.

Exercise is generally beneficial to all the animal functions. If man is destined to labour for his subsistence, the bread which he earns is scarcely more essential to his health and preservation, than the exertions by which he obtains it. Those whom the gifts of fortune have placed above the necessity of bodily labour are still compelled to take exercise; and when they cannot convert it into an amusement, they must submit to it as a task, or their health will soon experience the effects of their indolence.

EMILY.

That will never be my case, for exercise, unless it becomes fatigue, always gives me pleasure: and, so far from being a task, is a source of daily enjoyment. I often think what a blessing it is, that exercise, which is so conducive to health, should be so delightful; whilst fatigue, which is rather hurtful, instead of giving pleasure, occasions painful sensations. So that fatigue, no doubt, was intended to moderate our bodily exertions, as satiety puts a limit to our appetites.

MRS. B.

Certainly.—But let us not deviate too far from our subject. The bones are connected together by ligaments, which consist of a white, thick, flexible substance, adhering to their extremities, so far as to secure the joints firmly, though without impeding their motion. And the joints are moreover covered by a solid, smooth, elastic, white substance, called *cartilage*, the use of which is to allow, by its smoothness and elasticity, the bones to slide easily over one another, so that the joints may perform their office without difficulty or detriment.

Over the bones the *muscles* are placed: they consist of bundles of fibres, which terminate in a kind of string or ligament, by which they are fastened to the bones. The muscles are the organs of motion: by their power of dilatation and contraction they move the bones, which act as levers in all the motions of the body. The muscles are

of various degrees of strength or consistence in different species of animals. The mammiferous tribe, or those which suckle their young, in this respect occupy an intermediate place between birds and cold-blooded animals, such as reptiles and fishes; their muscles being neither so firm and strong as those of the former, nor so flaccid and weak as those of the latter.

EMILY.

The different degrees of firmness and solidity in the muscles of these several species of animals proceed, I imagine, from the different nature of the food on which they subsist?

MRS. B.

No, that is not supposed to be the case; for the human species, who are of the mammiferous tribe, live on more substantial food than birds; and yet the latter exceed them in muscular strength. We shall hereafter attempt to account for this difference; but let us now proceed in the examination of the animal functions.

The next class of organs consists of the vascular system, whose function is to convey the various fluids throughout the frame. These vessels are innumerable. The most considerable of them are those through which the blood circulates: they are of two kinds; the *arteries*, which convey it from the heart to the extremities of the body; and the *veins*, which bring it back into the heart.

There are also, in the animal frame, numerous sets of small transparent vessels, destined to absorb and convey different fluids into the blood: they are generally called the *absorbent* or *lymphatic* vessels; but it is to a portion of them only that the function of conveying into the blood the fluid called *lymph* is assigned.

EMILY.

Pray, what is the nature of that fluid?

MRS. B.

The nature and use of lymph have, I believe, never been perfectly ascertained; but it is supposed to consist of matter which has been previously animalised, and which, after answering the purpose for which it was intended, must, in regular rotation, make way for the fresh supplies produced by nourishment. The lymphatic vessels pump up this fluid from every part of the system, and convey it into the veins to be mixed with the blood which runs through them, and which is commonly called venous blood.

CAROLINE.

But does it not again enter into the animal system through that channel?

MRS. B.

Not entirely; for the venous blood does not return into the circulation until it has undergone a peculiar change, in which it throws off whatever is become useless.

Another sort of absorbent vessels pump up the *chyle* from the stomach and intestines, and convey it, after many circumvolutions, into the great vein near the heart.

Chyle is the substance into which food is converted by digestion.

EMILY.

It is, then, precisely the contrary of lymph : this last is rejected because it has performed its nutritive functions, while the former is received for the purpose of performing them.

CAROLINE.

One set of the absorbent vessels, then, is employed in bringing away the old materials which are no longer fit for use ; whilst the other set is busy in conveying into the blood the new materials which are to replace them. What a great variety of ingredients must enter into the composition of the blood !

MRS. B.

You must observe that there is also a great variety of substances to be secreted from it. We may compare the blood to a general receptacle or storehouse for all kinds of commodities, which are afterwards fashioned, arranged, and disposed of, as circumstances require.

Females are furnished with another system of absorbent vessels, which is destined to secrete milk for the nourishment of the young.

EMILY.

Pray, is not milk very analogous in its composition to blood ; for since the nursling derives its nourishment from that source only, it must contain every principle which the animal system requires ?

MRS. B.

Very true. Milk is found, by its analysis, to contain the principal materials of animal matter, albumen, oil, and phosphate of lime ; so that the suckling has but little trouble to digest and assimilate this nourishment. But we shall examine the composition of milk more fully hereafter.

In many parts of the body numbers of minute vessels are collected together in small bundles, called *glands*, from a Latin word meaning *acorn*, on account of the resemblance which some of them bear in shape to that fruit. The function of the glands is to *secrete* or separate certain matters from the blood.

The secretions are not only mechanical, but chemical separations from the blood ; for the substances thus formed, though contained in the blood, are not readily combined in that fluid. The secretions are of two kinds : those which form peculiar animal fluids, as bile, tears, saliva, &c. ; and those which produce the general materials of the animal system, for the purpose of recruiting and nourishing the several organs of the body — such as albumen,

gelatine, and fibrine : the latter may be distinguished by the name of *nutritive secretions*.

CAROLINE.

I am quite astonished to hear that all the secretions should be derived from the blood.

EMILY.

I thought that the bile was produced by the liver.

MRS. B.

So it is ; but the liver is nothing more than a very large gland, which secretes the bile from the blood.

The last of the animal organs which we have mentioned are the *nerves* : these are the vehicles of sensation, every other part of the body being, of itself, totally insensible.

CAROLINE.

They must, then, be spread throughout the frame, for we are everywhere susceptible of feeling.

EMILY.

Excepting the nails and the hair.

MRS. B.

And those are almost the only parts in which nerves cannot be discovered. The common source of all the nerves is the brain : thence they descend, some of them through different apertures in the skull, but the greatest part through the back bone, and extend themselves by innumerable ramifica-

tions throughout the whole body. They spread themselves over the muscles, penetrate the glands, wind round the vascular system, and even pierce into the interior of the bones. It is most probably through them that the communication is carried on between the mind and the other parts of the body; but in what manner they are acted on by the mind, and made to re-act on the body, is still a profound secret. Many hypotheses have been formed on this very obscure subject, but they are so vague or so erroneous, that it would be useless for us to spend our time in conjectures on an inquiry, which, in all likelihood, is beyond the reach of human capacity.

CAROLINE.

You have not mentioned those particular nerves which constitute the senses of hearing, seeing, smelling, and tasting?

MRS. B.

They are of the same nature as those which are dispersed over every part of the body, and give us the general sense of feeling. The various sensations which they produce arise from their peculiar situation and connection with the several organs of taste, smell, and hearing.

EMILY.

Yet these senses appear totally different from that of feeling?

MRS. B.

They are all of them sensations, but modified, according to the nature of the different organs in which the nerves are situated. For, as we have formerly observed, it is by contact only that the nerves are affected. Thus odoriferous particles must strike upon the nerves of the nose in order to excite the sense of smelling, in the same manner that taste is produced by the particular substance coming in contact with the nerves of the tongue. It is thus also that the sensation of sound is produced by the concussion of the air striking against the auditory nerve; and sight is the effect of light falling upon the optic nerve. These various senses, therefore, are affected only by the actual contact of particles of matter, in the same manner as that of feeling.

The different organs of the animal body, though easily separated and perfectly distinct, are loosely connected together by a kind of spongy substance, in texture somewhat resembling network, called the cellular membrane; and the whole is covered by the skin.

The *skin*, similar to the bark of vegetables, is formed of three coats. The external one is called the *cuticle* or *epidermis*; the second, which is called the *mucous membrane*, is of a thin soft texture, and consists of a mucous substance, which in negroes is black, and is the cause of their skin appearing of that colour.

CAROLINE.

Is then the external skin of negroes white like ours?

MRS. B.

Yes; but as the cuticle is transparent, as well as porous, the blackness of the mucous membrane is visible through it. The extremities of the nerves are spread over this membrane, so that the sensation of feeling is transmitted through the cuticle.

The internal covering of the muscles, which is properly the skin, is the thickest, the toughest, and most resisting of the whole: it is this membrane which is so essential in the arts, by forming leather when combined with tannin.

The skin which covers the animal body, as well as those membranes which form the coats of the vessels, consist almost exclusively of gelatine; and are capable of being converted into glue, size, or jelly.

The cavities between the muscles and the skin are usually filled with fat, which lodges in the cells of the membranous net before mentioned, and gives to the external form (especially in the human figure) that roundness, smoothness, and softness, so essential to beauty.

EMILY.

And the skin itself is, I think, a very ornamental part of the human frame, both from the fineness of its texture, and the variety and delicacy of its tints.

MRS. B.

This variety and harmonious gradation of colours proceed, not so much from the skin itself, as from the internal organs which transmit their several colours through it, these tints being only softened and blended by the colour of the skin, which is uniformly of a yellowish white.

Thus modified, the darkness of the veins appears of a pale blue colour, and the floridness of the arteries is changed to a delicate pink. In the most transparent parts the skin exhibits the bloom of the rose, whilst where it is more opaque its own colour predominates ; and at the joints where the bones are most prominent, their whiteness is often discernible. In a word, every part of the human frame seems to contribute to its external ornament ; and this not merely by producing a pleasing variety of tints, but by a peculiar kind of beauty which belongs to each individual part. Thus it is to the solidity and arrangement of the bones that the human figure owes the grandeur of its stature, and its firm and dignified deportment. The muscles delineate the form, and stamp it with energy and grace, and the soft substance which is spread over them smooths their ruggedness, and gives to the contour the gentle undulations of the line of beauty. Every organ of sense is a peculiar and separate ornament ; and the skin, which polishes the surface, and gives it that charm of colouring so inimitable

by art, finally conspires to render the whole the fairest work of the creation.

But now that we have acquired some notion of the composition of the animal frame, let us observe in what manner it provides for its support, and how the several organs, which form so complete a whole, are nourished and maintained.

This will lead us to a more particular explanation of the internal organs, which will take up some time, and render it expedient for us to defer it till our next interview. In the examination of these organs we shall not meet with so much apparent beauty, because they were not intended by nature to be exhibited to view ; but the beauty of design in the internal organisation of the animal frame, is, if possible, still more remarkable than that of the external parts.

CONVERSATION XXV.

ON ANIMALISATION, NUTRITION, AND
RESPIRATION.

MRS. B.

WE have now learnt of what materials the animal system is composed, and have formed some idea of the nature of its organisation. In order to complete the subject, it remains for us to examine in what manner it is nourished and supported.

Vegetables, we have observed, receive sustenance from various substances, either in an elementary form, or in a very simple state of combination; such as carbon, water, and salts, which they suck up from the soil; and carbonic acid and oxygen, which they absorb from the atmosphere.

Animals, on the contrary, feed on substances of the most complicated kind: they derive their sustenance, some from the animal creation, others from the vegetable kingdom, and some from both; but they receive no nourishment from the mineral kingdom. The stomach is totally incapable of converting either mineral or elementary bodies

into animal substance. It can digest and assimilate such food only as has passed through the vegetable system; therefore, should plants fail, animals must perish also.

EMILY.

Yet we eat animal as well as vegetable food.

MRS. B.

True; but observe that the flesh on which we feed, has already been prepared for us by passing through the vegetable system.

CAROLINE.

Oh, yes; the plants have cooked it for us. But then we eat salt, Mrs. B., which is muriate of soda, and that belongs exclusively to the mineral kingdom?

MRS. B.

Salt is pleasant to the taste, in combination with other savours, and it promotes the digestion of food, but affords none itself.

There is a difference between eating and drinking, and receiving nourishment. Whatever we swallow passes into the stomach; but unless it is digested there, and afterwards assimilated to the animal body, it cannot afford it nourishment.

It is worthy of observation, that the higher we ascend in the scale of existence, the more the beings of which it is formed are dependent on those of an inferior order. The elementary bodies as

well as their various combinations in the mineral kingdom, are entirely independent of the animal and vegetable creation. It is now well ascertained that minerals existed many centuries before the era of organised beings. When plants were created, they required both a soil and an atmosphere to nourish and support them, and thus became dependent on the mineral kingdom; and animals, the last and highest order of created beings, are, as we have seen, entirely dependent on the two other kingdoms.

CAROLINE.

If we are dependent on them in one point of view, we have entire command over them in another; for we make them contribute not only to our nourishment, but to our clothing, our lodging, and our comforts and enjoyments, in an endless variety of ways.

And man, not satisfied with enjoying either kind of food in its simple state, has invented the art of combining them together in a thousand ways, and of rendering even the mineral kingdom subservient to its refinements.

EMILY.

Nor is this all: for our delicacies are collected from the various climates of the earth, so that the four quarters of the globe are often obliged to contribute to the preparation of our simplest dishes.

But the very complicated substances which constitute the nourishment of animals do not, I suppose, enter into their system, in their actual state of combination?

MRS. B.

So far from it, that they not only undergo a new arrangement of their parts, but a selection is made of such as are most proper for the nourishment of the body; and those only enter into the system, and are animalised.

EMILY.

And by what organs is this process performed?

MRS. B.

Chiefly by the stomach, which is the organ of digestion, and the principal regulator of the animal frame.

Digestion is the first step towards nutrition. It consists, first, in reducing into one homogeneous mass the various substances which are taken as nourishment; this is performed by chewing and mixing the solid aliment with the saliva, which reduces it to a soft mass, in which state it is swallowed and conveyed into the stomach, where it is more completely dissolved by the *gastric juice*.

This fluid, which is secreted into the stomach by appropriate glands, is so powerful a solvent that scarcely any substances will resist its action.

EMILY.

The coats of the stomach, however, cannot be

attacked by it, otherwise we should be in danger of having them destroyed when the stomach was empty.

MRS. B.

They are probably not subject to its action ; as long, at least, as life continues. But it appears, that when the gastric juice has no foreign substance to act upon, it is capable of occasioning a degree of irritation in the coats of the stomach, which produces the sensation of hunger. The gastric juice, together with the heat and muscular action of the stomach, convert the aliment into an uniform pulpy mass called chyme. This passes into the intestines, where it meets with the bile and some other fluids, by the agency of which, and by the operation of other causes hitherto unknown, the chyme is changed into chyle, a much thinner substance, somewhat resembling milk, which is pumped by immense numbers of small absorbent vessels spread over the internal surface of the intestines. These, after many circumvolutions, gradually meet and unite into large branches, till they at length collect the chyle into one vessel, which pours its contents into the great vein near the heart ; by which means the food, thus prepared, enters into the circulation.

CAROLINE.

And how does the blood, thus formed, nourish the body and supply the secretions ?

MRS. B.

Before this can be explained to you, you must first allow me to complete the formation of the blood. The chyle may, indeed, be considered as forming the chief ingredient of blood; but this fluid is not perfect until it has passed through the lungs, and undergone (together with the blood that has already circulated) certain necessary changes which are effected by RESPIRATION.

CAROLINE.

I am very glad that you are going to explain the nature of respiration: I have often longed to understand it; for though we talk incessantly of *breathing*, I never knew precisely what purpose it answered.

MRS. B.

It is, indeed, one of the most interesting processes imaginable; but, in order to understand this function well, it will be necessary to enter into some previous explanations. Tell me, Emily, — what do you understand by respiration?

EMILY.

Respiration, I conceive, consists simply in alternately *inspiring* air into the lungs, and *expiring* it from them.

MRS. B.

Your answer will do very well as a general definition. But I suppose you would like to know

for what purpose we breathe, and how the inspiration and expiration of air effect that purpose?

EMILY.

Every one knows that breathing keeps us alive, though by what means I am totally ignorant, but I conclude it is a chemical process.

MRS. B.

The process of respiration is both *mechanical* and *chemical*. But in order to form a tolerably clear notion of the various phenomena of respiration, there are many circumstances to be taken into consideration.

The mechanism of breathing depends on the alternate expansions and contractions of the chest, that large cavity in which the lungs are contained. When the chest dilates, this cavity is enlarged, and the air rushes in at the mouth, to fill up the vacuum formed by the dilatation; when it contracts, the cavity is diminished, and the air forced out again.

CAROLINE.

I thought that it was the lungs which contracted and expanded in breathing.

MRS. B.

They do also, but their action is only the consequence of that of the chest. The lungs, together with the heart and largest blood-vessels, in a manner fill up the cavity of the chest; these could

not therefore dilate, if the chest did not previously expand ; and, on the other hand, when the chest contracts, the lungs are necessarily compressed, and the air forced out of them.

CAROLINE.

The lungs, then, are like bellows, and the chest is the power that works them.

MRS. B.

Precisely so. Here is a curious little figure (Plate XVIII. fig. 5.), which will assist me in explaining the mechanism of breathing.

CAROLINE.

What a droll figure ! a little head fixed upon a glass bell, with a bladder tied over the bottom of it !

MRS. B.

You must observe that there is another bladder within the glass, the neck of which communicates with the mouth of the figure : this represents the lungs contained within the chest ; the external bladder, which you see is tied loose, represents a muscular membrane, called the *diaphragm*, which separates the chest from the lower part of the body. By the chest, therefore, I mean that large cavity in the upper part of the body contained within the ribs, the neck, and the diaphragm : this membrane is muscular, and capable of contraction and dilatation. The contraction may be imitated

by drawing the bladder tight over the bottom of the receiver, as I can easily do by squeezing it in my hand, when the air in the bladder, which represents the lungs, will be forced out through the mouth of the figure ——

EMILY.

See, Caroline, how it blows the flame of the candle in breathing !

MRS. B.

By letting the bladder loose again, we imitate the dilatation of the diaphragm ; and the cavity of the chest being thus enlarged, the lungs expand, and the air rushes in to fill them.

EMILY.

This figure, I think, gives a very clear idea of the act of breathing.

MRS. B.

It illustrates, tolerably well, the action of the lungs and diaphragm ; but those are not the only powers concerned in the enlargement or diminution of the cavity of the chest ; the ribs are also possessed of a muscular motion for the same purpose ; they are alternately drawn in, edgeways, to assist the contraction, and stretched out, like the hoops of a barrel, to contribute to the dilatation of the chest.

EMILY.

I always supposed that the elevation and de-

pression of the ribs were the consequence, not the cause, of breathing.

MRS. B.

It is exactly the reverse. The muscular action of the diaphragm, together with that of the ribs, are the *causes* of the contraction and expansion of the chest; and the air rushing into, and being expelled from the lungs, are only *consequences* of those actions.

CAROLINE.

I confess that I thought the act of breathing began by opening the mouth for the air to rush in, and that it was the air alone which, by alternately rushing in and out, occasioned the dilatations and contractions of the lungs and chest.

MRS. B.

Try the experiment of merely opening your mouth: the air will not rush in till, by an internal muscular action, you produce a vacuum: yes, just so: your diaphragm is now dilated, and the ribs expanded. But you will not be able to keep them long in that position. Your lungs and chest are already resuming their former state, and expelling the air with which they had just been filled. This mechanism goes on more or less rapidly; but, in general, a person at rest and in health will breathe between fifteen and twenty-five times in a minute.

We may now proceed to the chemical effects of respiration; but, for this purpose, it is necessary

that you should previously have some notion of the *circulation* of the blood. Tell me, Caroline, what do you understand by the circulation of the blood?

CAROLINE.

I am delighted that you come to that subject, for it is one that has long excited my curiosity. But I cannot conceive how it is connected with respiration. My idea of the circulation is, that the blood runs from the heart, through the veins, all over the body, and back again to the heart.

MRS. B.

I could hardly have expected a better definition from you : it is, however, not quite correct ; for you do not distinguish the *arteries* from the *veins*, which, as we have already observed, are two distinct sets of vessels, each having its own peculiar functions. The arteries convey the blood from the heart to the extremities of the body, and the veins bring it back into the heart.

This sketch will give you an idea of the manner in which some of the principal veins and arteries of the human body branch out of the heart, which may be considered as a common centre to both sets of vessels. The heart is a kind of strong elastic bag, or muscular cavity, which possesses a power of dilating and contracting itself, for the purposes of alternately receiving and expelling the blood, in order to carry on the process of circulation.

EMILY.

Why are the arteries in this drawing painted red, and the veins purple?

MRS. B.

It is to point out the difference of the colour of the blood in these two sets of vessels.

CAROLINE.

But if it is the same blood which flows from the arteries into the veins, how can its colour be changed?

MRS. B.

This change arises from various circumstances. In the first place, during its passage through the arteries, the blood undergoes a considerable alteration; some of its constituent parts being gradually separated from it, for the purpose of nourishing the body, and of supplying the various secretions. In consequence of this, the florid arterial colour of the blood changes by degrees to a deep purple, which is its constant colour in the veins. On the other hand, the blood is recruited during its return through the veins by the fresh chyle, or imperfect blood, which has been produced by food; and it receives also lymph from the absorbent vessels, as we have before mentioned. After having undergone these several changes, the blood returns to the heart in a state very different from that in which it left it. It is loaded with a greater proportion of hydrogen and carbon, and is no longer fit

for the nourishment of the body, or other purposes of circulation.

EMILY.

And in this state does it mix in the heart with the pure florid blood which runs into the arteries?

MRS. B.

No. The heart is divided into two cavities or compartments, called the *right* and *left ventricles*. The left ventricle is the receptacle for the pure arterial blood, previous to its circulation; whilst the venous, or impure blood, which returns to the heart after having circulated, is received into the right ventricle previous to its purification; which I shall presently explain.

CAROLINE.

I own that I always thought the same blood circulated again and again through the body, without undergoing any change.

MRS. B.

Yet you must have supposed that the blood circulated for some purpose.

CAROLINE.

I knew that it was indispensable to life, but had no idea of its real functions.

MRS. B.

But now that you understand that the blood conveys nourishment to every part of the body, and supplies the various secretions, you must be

sensible that it cannot constantly answer these objects without being proportionately renovated and purified.

CAROLINE.

But does not the chyle answer this purpose ?

MRS. B.

Only in part. It renovates the nutritive principles of the blood, but does not relieve it from the superabundance of water and carbon with which it is encumbered.

EMILY.

How, then, is this effected ?

MRS. B.

By RESPIRATION. This is one of the grand mysteries which modern chemistry has disclosed. When the venous blood enters the right ventricle of the heart, this contracts by its muscular power, and throws the blood through a large vessel into the lungs, which are contiguous, and through which it circulates by millions of small ramifications. Here it comes in contact with the air which we breathe. The action of the air on the blood in the lungs is, indeed, concealed from our immediate observation ; but we are able to form a tolerably accurate judgment of it from the changes effected not only in the blood, but also in the air expired.

The air, after passing through the lungs, is found to contain all the nitrogen inspired, but to

have lost part of its oxygen, and to have acquired a portion of watery vapour and of carbonic acid gas. Hence it is inferred, that, when the air comes in contact with the venous blood in the lungs, the oxygen attracts from it the superabundant quantity of carbon and hydrogen, with which it has become loaded during the circulation, converting the first into carbonic acid, and the other into water. This gaseous acid, together with the watery vapour, being then expired*, the blood is restored to its former purity, that is, to the state of arterial blood, and is thus again enabled to perform its various functions.

CAROLINE.

This is truly wonderful! Of all that we have yet learned, I do not recollect any thing that has appeared to me so curious and interesting. I almost believe that I should like to study anatomy, though I have hitherto had so disgusting an idea of it. Pray to whom are we indebted for these beautiful discoveries?

MRS. B.

Priestley and Crawford, in this country, and Lavoisier, in France, are the principal inventors of the theory of respiration. Some years later the subject was further illustrated and simplified

*. The quantity of moisture discharged by the lungs in 24 hours may be computed at eight or nine ounces.

by the accurate experiments of Messrs. Allen and Pepys, and more recently by those of Messrs. Liebig and Rignault. But the still more important and more admirable discovery of the circulation of the blood was made long before by our immortal countryman Harvey.

EMILY.

Indeed, I never heard any thing that delighted me so much as this theory of respiration. But I hope, Mrs. B., that you will enter a little more into particulars before you dismiss so interesting a subject. We left the blood in the lungs to undergo the salutary change ; but how does it thence spread to all parts of the body ?

MRS. B.

After circulating through the lungs, the blood is collected into four large vessels, by which it is conveyed into the left ventricle of the heart ; whence it is propelled to all the different parts of the body by a large artery, which gradually ramifies into millions of small arteries through the whole frame.

From the extremities of these little ramifications the blood is transmitted to the veins, which bring it back to the heart and lungs, to go round again and again in the manner we have just described. You see, therefore, that the blood actually undergoes two circulations ; the one through the lungs, by which it is converted into pure arterial blood ; the other, or general circulation, by which nou-

ishment is conveyed to every part of the body : and these are both equally indispensable to the support of animal life.

EMILY.

But whence proceeds the excess of carbon and of hydrogen with which the blood is impregnated when it comes into the lungs ?

MRS. B.

The vegetable system contains more carbon and more hydrogen than the animal system. Vegetables having a great deal of hard wood to form, require much more carbon than animals, the hardest and most solid parts of whose frame, the bones, consist of phosphate of lime. Now, as we eat a very considerable quantity of vegetable food, a great deal more carbon enters into our system than we can assimilate, and which, therefore, must be got rid of. We consume prodigious quantities of carbon in bread, or any food made from grain, where it is deposited in the seed under the form of starch, which consists of carbon and hydrogen ; and though starch affords the best nourishment for germinating plants, it is superabundant in the animal economy.

CAROLINE.

So, then, if we were not obliged to eat so much useless starch mixed up by Nature with our food, we might live without breathing, for we should

have no excess of carbon and hydrogen to get rid of? How curious that would be! I cannot help wondering that Nature, who is so excellent an economist in all her arrangements, should have encumbered the animal frame with such a useless quantity of carbon and hydrogen.

MRS. B.

Before you throw any blame on Nature, it would be well to reflect whether she may not have some wise design in view which we have not been able to penetrate. This is the conclusion I always draw in such cases. But such faith in the wisdom of her arrangements is not requisite in the present instance, since I shall be able to convince you that starch, so far from being useless in the animal economy, performs one of the most delicate and important processes of animal life; but you must have patience, and for the present be satisfied with knowing that carbon and hydrogen exist in a greater proportion in blood than in organised animal matter. The blood, therefore, after supplying its various secretions, becomes loaded with an excess of carbon and hydrogen, which is carried off by respiration.

CAROLINE.

I wonder what quantity of carbon may be expelled from the blood by respiration in the course of the day.

MRS. B.

It appears, by the experiments of Messrs. Allen and Pepys, that about 40,000 cubic inches of carbonic acid gas are emitted from the lungs of a healthy person daily ; which is equivalent to *eleven ounces* of solid carbon every 24 hours.

EMILY.

What an immense quantity ! And pray how much carbonic acid gas do we expel from our lungs at each expiration ?

MRS. B.

The quantity of air which we take into our lungs at each inspiration is about 40 cubic inches, which contain a little less than 10 cubic inches of oxygen : and of those 10 inches, one eighth is converted into carbonic acid gas on passing once through the lungs *, a change which is sufficient to prevent air which has only been breathed once from allowing a taper to burn in it.

CAROLINE.

Pray, how does the air come in contact with the blood in the lungs ?

MRS. B.

I cannot answer this question without entering into an explanation of the nature and structure of the lungs. You recollect that the venous blood,

* The bulk of carbonic acid gas formed by respiration is exactly the same as that of the oxygen gas which disappears.

on being expelled from the right ventricle, enters the lungs to go through what we may call the lesser circulation ; the large trunk or vessel which conveys it, branches out, at its entrance into the lungs, into an infinite number of very fine ramifications. The windpipe, through which the air passes from the mouth into the lungs, likewise spreads out into a corresponding number of air-vessels, which follow the same course as the blood-vessels, forming millions of very minute air-cells. These two sets of vessels are so interwoven as to form a sort of net-work, connected into a kind of spongy mass, in which every particle of blood must necessarily come in contact with a particle of air.

CAROLINE.

But since the blood and the air are contained in different vessels, how can they come into contact ?

MRS. B.

They act on each other through the membrane which forms the coats of these vessels ; for, although this membrane prevents the blood and the air from mixing together in the lungs, its texture is so delicate that it offers no impediment to their chemical action on each other.

EMILY.

Are the lungs composed entirely of blood-vessels and air-vessels ?

MRS. B.

I believe they are, with the addition only of

nerves, and of a small quantity of the cellular substance before mentioned, which connects the whole into an uniform mass.

EMILY.

Pray, why are the lungs always spoken of in the plural number? Are there more than one?

MRS. B.

Yes; for though they form but one organ, they really consist of two compartments, called *lobes*, which are enclosed in separate membranes or bags, each occupying one side of the chest, and being in close contact with each other, but without communicating together. This is a beautiful provision of Nature; in consequence of which, if one of the lobes be wounded, the other performs the whole process of respiration till the first is healed. And people have even been known to live and enjoy health, after having lost one of the lobes of the lungs, either by accident or disease.

The blood, thus completed by the process of respiration, forms the most complex of all animal compounds, since it contains not only the numerous materials necessary for the production of the various secretions, as saliva, tears, &c., but likewise all those which are required to nourish the several parts of the body, as the muscles, bones, nerves, glands, &c.

EMILY.

There seems to be a singular analogy between

the blood of animals and the sap of vegetables ; for each of these fluids contains the several materials destined for the nutrition of the numerous class of bodies to which they respectively belong.

MRS. B.

Nor is the production of these fluids in the animal and vegetable systems entirely different ; for the absorbent vessels, which pump up the chyle from the stomach and intestines, may be compared to the absorbents of the roots of plants, which suck up the nourishment from the soil.

CAROLINE.

And we also take in oxygen from the atmosphere, though not for the same purpose ; for plants do not want to breathe ; they cannot be incumbered with carbon and hydrogen, for the more a tree receives the faster it grows, the higher the stem rises, the further roots and branches spread, and the more plentiful are the leaves, blossoms, and fruit.

MRS. B.

The analogy between the sap and the blood may be still further traced, if we follow the latter in the course of its circulation ; for, in the living animal, we find every where organs which are possessed of a power to secrete from the blood, and appropriate to themselves the ingredients requisite for their support.

CAROLINE.

But whence do these organs derive their respective powers ?

MRS. B.

From a peculiar organisation, the secret of which no one has yet been unable to unfold. But it must be ultimately by means of the vital principle, that both their mechanical and chemical powers are brought into action.

I cannot dismiss the subject of circulation without mentioning *perspiration*, a secretion which is immediately connected with it, and acts a most important part in the animal economy.

CAROLINE.

Is not this secretion likewise made by appropriate glands?

MRS. B.

No: it is performed by the extremities of the arteries, which penetrate through the skin and terminate under the cuticle, through the pores of which the perspiration issues. When this fluid is not secreted in excess, it is *insensible*, because it is dissolved by the air as it exudes from the pores; but when it is secreted faster than it can be dissolved, it becomes *sensible*, as it retains its liquid form.

EMILY.

This secretion bears a striking resemblance to the transpiration of the sap of plants. They both consist of the most fluid parts, and both exude from the surface by the extremities of the vessels through which they circulate.

MRS. B.

Nor does the analogy stop here ; for within these few years it has been ascertained that a portion of the sap returns into the roots of the plants, and thence descends into the soil ; the resemblance, therefore, between the animal and the vegetable circulation is become still more obvious. The latter, however, is far from being complete ; since, as we observed before, it consists only in a rising and descending of the sap, whilst in animals the blood actually *circulates* through every part of the system.

We have now, I think, traced the process of nutrition, from the introduction of the food into the stomach to its finally becoming a constituent part of the animal frame. This will, therefore, be a fit period to conclude our present conversation.

CAROLINE.

But, Mrs. B., you have got rid of the starch by respiration, without telling us what is the important part it plays in the animal economy, which I am so anxious to know ?

MRS. B.

You must restrain your curiosity till our next interview, when we shall complete what further remarks we have to make on the animal economy.

CONVERSATION XXVI.

ON ANIMAL HEAT, AND ON VARIOUS ANIMAL PRODUCTS

EMILY.

SINCE our last interview, I have been thinking much of the theory of respiration; and I cannot help being struck with the resemblance which appears to bear to combustion: for the air undergoes the same change in respiration as in combustion: its oxygen combining with carbon and hydrogen, producing carbonic acid and water.

MRS. B.

I am much pleased that this idea has occurred to you: these two processes, which in appearance are so analogous, are believed to be actually the same; and that combustion really takes place in the lungs; not of the blood, but of the superfluous carbon and hydrogen with which it is loaded.

CAROLINE.

A combustion in our lungs! that is a curious idea indeed! and I begin to be alarmed, lest we should be burnt. But we have seen the combustion both of carbon and of hydrogen in oxygen gas and in common air: in the former it gives out:

strong blaze of light, and a great quantity of heat, and in the latter it produces fully sufficient to set us on fire; and I know not how you can call the action of the air on the blood in the lungs combustion, when neither light nor heat are produced by it?

EMILY.

I was going to make the same objection. — Yet I do not conceive how the oxygen can combine with the carbon and hydrogen without disengaging heat.

MRS. B.

Whether any light be evolved I cannot pretend to determine; but heat is certainly disengaged in considerable and very sensible quantities. It has been calculated that the heat produced by respiration in twelve hours, in the lungs of a healthy person, is such as would melt about one hundred pounds of ice. And this is the principal, if not the only source of ANIMAL HEAT.

EMILY.

How wonderful! that the very process which elaborates and purifies the blood should afford an inexhaustible supply of internal heat!

CAROLINE.

Oh! now I guess it; you need not explain it, Mrs. B.; it is the starch which is burnt by the oxygen in our lungs; and it is to this very starch,

which I have so much abused, that we are indebted for the production of animal heat !

MRS. B.

You are quite right. Starch, I told you, consists of carbon and hydrogen. The oxygen, on entering the lungs, separates these two elements of starch, and divides itself between them, burning both, and converting the carbon into carbonic acid and the hydrogen into water; both of which are expired, and the only vestige the lungs retain of these bodies is the heat resulting from their combustion. This process is repeated every time we breathe.

EMILY.

It appears then that starch affords no food to the animal frame, but is reserved wholly for fuel,—for the combustion which produces animal heat.

MRS. B.

That at least is the case with the starch which is brought to the lungs by the venous blood. This theory of animal heat I have given you in its original simplicity, such nearly as it was first proposed by Black and Lavoisier. It appeared equally clear and ingenious; and was generally adopted. But, on consideration, it was objected, that if the whole of the animal heat was evolved in the lungs, it would necessarily be much less in the extremities of the body than immediately at its source; which is not found to be the case. This

objection, however, is now satisfactorily removed by the following explanation :—Venous blood has been found by experiment to have *less capacity for heat* than arterial blood; whence it follows that the blood, in gradually passing from the arterial to the venous state, during the circulation, parts with a portion of caloric, by means of which heat is diffused through every part of the body.”*

CAROLINE.

More and more admirable! The cause of animal heat was always a perfect mystery to me, and I am delighted with its explanation. But pray, Mrs. B., can you tell me what is the reason of the increase of heat which takes place in fever?

EMILY.

Is it not because we then breathe quicker, and, therefore, more heat is disengaged in the system?

MRS. B.

That may be one reason: but I should think that the principal cause of the heat experienced in fever proceeds from a deficiency of vent for the caloric which is generated in the body. One of the most considerable secretions is insensible perspiration: this is constantly carrying off caloric in

* This ingenious explanation has been lately called in question by many scientific men; the fact, that venous blood has less capacity for heat than arterial blood, not being considered as sufficiently well demonstrated by experiment.

a latent state ; but during the hot stage of a fever, the pores are so contracted, that all perspiration ceases, and the accumulation of caloric in the body occasions those burning sensations which are so painful.

EMILY.

This is, no doubt, the reason why the perspiration which often succeeds the hot stage of a fever affords so much relief. If I had known this theory of animal heat when I had a fever last summer, I think I should have found some amusement in watching the chemical processes that were going on within me.

CAROLINE.

But exercise likewise produces animal heat, and that must be quite in a different manner.

MRS. B.

Not so much as you think ; for the more exercise you take, the more the body is exhausted and requires recruiting. For this purpose the circulation of the blood is quickened, the breath proportionably accelerated, and, consequently, a greater quantity of caloric evolved.

CAROLINE.

True ; after running very fast, I gasp for breath, my respiration is quick and hard, and it is just then that I begin to feel hot. It would seem, then, that violent exercise should produce fever.

MRS. B.

Not if the person be in a good state of health ; for the additional caloric is then carried off by the perspiration which succeeds.

EMILY.

What admirable resources nature has provided for us ! By the production of animal heat she has enabled us to keep up the temperature of our bodies above that of inanimate objects ; and whenever this source becomes too abundant, the excess is carried off by perspiration.

MRS. B.

It is by the same law of nature that we are enabled, in all climates, and in all seasons, to preserve our bodies of an equal temperature, or at least very nearly so.

CAROLINE.

You cannot mean to say that our bodies are of the same temperature in summer and in winter, in England and in the West Indies ?

MRS. B.

Yes, I do ; at least if you speak of the temperature of the blood, and the internal parts of the body : for those which are immediately in contact with the atmosphere (such as the hands and face) will occasionally get warmer, or colder, than the internal or more sheltered parts. If you put the bulb of a thermometer in your mouth, which is

the best way of ascertaining the real temperature of your body, you will scarcely perceive any difference in its indication, whatever may be the difference of temperature of the atmosphere.

CAROLINE.

Then do you mean to say that when I feel overcome by heat, I am really not hotter than when I am shivering with cold?

MRS. B.

When a person in health feels very hot, whether from internal heat, from violent exercise, or from the temperature of the atmosphere, his body is certainly a little warmer than when he feels very cold; but this difference is much smaller than our sensations would make us believe; and the natural standard is soon restored by rest and by perspiration. It is chiefly the external parts that are warmer; and I am sure that you will be surprised to hear that the internal temperature of the body scarcely ever descends below ninety-five or ninety-six degrees, and seldom attains one hundred and four or one hundred and five degrees, even in the most violent fevers.

EMILY.

The greater quantity of caloric, therefore, which we receive from the atmosphere, in summer, cannot raise the temperature of our bodies beyond certain limits, as it does that of inanimate bodies,

because an excess of caloric is carried off by perspiration.

CAROLINE.

But the temperature of the atmosphere, and, consequently, that of inanimate bodies, is surely never so high as that of animal heat?

MRS. B.

Very seldom in this climate; but in the East and West Indies, and sometimes in the southern parts of Europe, the atmosphere is frequently above ninety-eight degrees, which is the common temperature of animal heat. Indeed, even in this country, it occasionally happens that the sun's rays, setting full on an object, elevate its temperature above that point.

In illustration of the power which our bodies have to resist the effects of external heat, Sir Charles Blagden, with some other gentlemen, made several very curious experiments. He remained for some time in an oven, heated to a temperature not much inferior to that of boiling water, without suffering any other inconvenience than a profuse perspiration, which he supported by drinking plentifully. These experiments were repeated at Paris by M. De la Roche. This enterprising philosopher covered the whole of his body, excepting the forehead, with a varnish which effectually prevented all perspiration, and in this state he entered an oven, heated to the temperature of boil-

ing water. Nature, which abounds in resources, obviated this difficulty by affording a vent to the whole of the perspiration at the forehead, which sent forth a copious stream of water.

EMILY.

He could scarcely consider the perspiration as an inconvenience, since it saved him from being baked by giving vent to the excess of caloric.

CAROLINE.

I always thought, I confess, that it was from the heat of the perspiration that we suffered in summer.

MRS. B.

You now find that you are quite mistaken. Whenever evaporation takes place, cold, you know, is produced in consequence of a quantity of caloric being carried off in a latent state: this is the case with perspiration, and it is thus that it affords relief. It is on this account, also, that we are so liable to *catch cold* when in a state of profuse perspiration. It is for the same reason that tea is often refreshing in summer, though it appears to heat you at the moment you drink it.

EMILY.

And in winter, on the contrary, tea is pleasant on account of the heat it communicates, which, not being in excess, does not produce perspiration.

MRS. B.

We have, then, rather to guard against a defi-

ciency than a redundancy of caloric ; therefore tea will not excite perspiration in winter, unless after dancing, or any other violent exercise.

CAROLINE.

What is the reason that it is dangerous to eat ice after dancing, or to drink any thing cold when you are very hot ?

MRS. B.

Because the loss of heat arising from the perspiration, conjointly with the chill occasioned by the cold draught, occasions a greater loss of caloric than can be borne with safety, unless you continue to use the same exercise after drinking that you did before ; for the heat occasioned by the exercise will counteract the effects of the cold drink, and the danger will be removed. You may, however, contrary to the common notion, consider it as a rule, that cold liquids may, at all times, be drunk with perfect safety, however hot you may feel, provided you are not at the moment in a state of great perspiration, and on condition that you keep yourself in gentle exercise afterwards.

EMILY.

But since we are furnished with such resources against the extremes of heat or cold, I should have thought that all climates would have been equally wholesome.

MRS. B.

That is true, in a certain degree, with regard

to those who have been accustomed to them from birth; for we find that the natives of those climates which we consider as most deleterious are as healthy as ourselves; and if such climates are unwholesome to those who are habituated to a more moderate temperature, it is because the animal economy does not easily accustom itself to considerable changes.

CAROLINE.

But pray, Mrs. B., if the circulation preserves the body of a uniform temperature, how does it happen that animals are sometimes frozen?

MRS. B.

Because, if more heat be carried off by the atmosphere than the circulation can supply, the cold will finally prevail, the heart will cease to beat, and the animal will be frozen. And, likewise, if the body remained long exposed to a degree of heat greater than the perspiration could carry off, it would, at last, lose the power of resisting its destructive influence.

CAROLINE.

Fish, I suppose, have no animal heat, but partake of the temperature of the water in which they live; and their coldness, no doubt, proceeds from their not breathing?

MRS. B.

All kinds of fish breathe more or less, though in a much smaller degree than land animals. Nor

are they entirely destitute of animal heat, though, for the same reason, they are much colder than other creatures. They have comparatively but a very small quantity of blood; therefore but very little oxygen is required, and a proportionally small quantity of animal heat is generated.

CAROLINE.

But how can fish breathe under water?

MRS. B.

They breathe by means of the air which is dissolved in the water; and if you put them into water deprived of air by boiling, they are quickly suffocated.

If a fish be confined in a vessel of water closed from the air, it soon dies; and another fish put in afterwards would be killed immediately; as all the air had been previously consumed.

CAROLINE.

Are there any species of animals which breathe more than we do?

MRS. B.

Yes; birds, of all animals, breathe the greatest quantity of air in proportion to their size; and it is to this that they are supposed to owe the peculiar firmness and strength of their muscles, by which they are enabled to support the violent exertion of flying.

This difference between birds and fish, which may be considered as the two extremes of the scale

of muscular strength, is well worth observing. Birds, residing constantly in the atmosphere, surrounded by oxygen, and respiring it in greater proportions than any other species of animals, are endowed with a superior degree of muscular strength, whilst the muscles of fish, on the contrary, are flaccid and oily; these animals are comparatively feeble in their motions, and their temperature is scarcely above that of the water in which they live. This is, in all probability, owing to their imperfect respiration; the quantity of hydrogen and carbon, which is, in consequence, accumulated in their bodies, forms the oil which is so strongly characteristic of that species of animals, and which relaxes and softens the small quantity of fibrine contained in their muscles.

CAROLINE.

But, Mrs. B., there are some species of birds that frequent both elements; as, for instance, ducks, and other water-fowl. Of what nature is the flesh of these?

MRS. B.

It partakes of the oily nature, and even in taste sometimes resembles that of fish. This is the case not only with the various kinds of water-fowls, but with all other amphibious animals, as the otter, the crocodile, the lizard, &c.

CAROLINE.

And what is the reason that reptiles are so deficient in muscular strength?

MRS. B.

It is because they usually live under ground, and seldom come into the atmosphere. They have imperfect organs of respiration; they partake, therefore, of the soft oily nature of fish; indeed, many of them are amphibious, as frogs, toads, and snakes; and very few of them find any difficulty in remaining a length of time under water. Whilst, on the contrary, the insect tribe, which are so strong in proportion to their size, and alert in their motions, partake of the nature of birds, air being their peculiar element, and their organs of respiration being comparatively larger than in other classes of animals.

EMILY.

But I wonder that the loss of carbon and hydrogen made by animals in breathing does not exhaust them. I should have thought that we should have grown thin and weak by such constant breathing, both day and night, sleeping or waking?

MRS. B.

A full-grown man in health retains pretty much the same weight and strength of frame from year to year. The loss he experiences in breathing is only the riddance of a useless load, and the bulk and weight of this load are exactly replaced by the food he eats. So he exchanges what he does not want for that which he does want.

A child breathes quicker than a man, and consequently is obliged to take in food oftener and in greater quantity, in proportion to its relative size; and men breathe more frequently, can eat more, and do more labour in a cold climate than in a hot one—in winter than in summer.

I have now given you a short account of the principal animal functions. However interesting the subject may appear to you, a fuller investigation of it would, I fear, lead us too far from our object.

EMILY.

Yet I shall not quit it without much regret; for of all the applications of chemistry, these appear to me the most curious and most interesting.—But, Mrs. B., I must remind you that you promised to give us some account of the nature of *milk*.

MRS. B.

True. There are several other animal productions which deserve likewise to be mentioned. We shall begin with milk, which is certainly the most important and the most interesting of all the animal secretions.

Milk, like every other animal substance, ultimately yields, by analysis, oxygen, hydrogen, carbon, and nitrogen. These are combined in it, under the forms of albumen, gelatine, oil, and water. But milk contains, besides, a considerable portion of phosphate of lime, the purposes of which

I have already informed you, is to strengthen and harden the tender bones of the suckling.

To reduce milk to its elements would be a very complicated, as well as useless operation; but this fluid, without any chemical assistance, may be decomposed into three parts, *cream*, *casein* or *curds*, and *whey*. These constituents of milk have but a very slight affinity to each other, and you find accordingly that cream separates from milk by mere standing. It consists chiefly of oil, which, being lighter than the other parts of the milk, gradually rises to the surface. It is of this, you know, that butter is made, which is nothing more than oxygenated cream.

EMILY.

Is the cream oxygenated by churning?

MRS. B.

Its oxygenation commences*, previous to churning, merely by standing exposed to the atmosphere, from which it absorbs oxygen. The process is afterwards completed by churning: the violent motion which this operation occasions brings every particle of cream in contact with the atmosphere, and thus facilitates its oxygenation.

CAROLINE.

But the effect of churning, I have often observed

* It is proper to mention that the oxygenation of cream, which is taken for granted in the above theory, is a disputed fact.

in the dairy, is to separate the cream into two substances, butter and butter-milk.

MRS. B.

That is to say, in proportion as the oily particles of the cream become oxygenated, they separate from the other constituent parts of the cream in the form of butter. So, by churning, you produce, on the one hand, butter, or oxygenated oil; and, on the other, butter-milk, or cream deprived of oil. But if you make butter by churning new milk instead of cream, the butter-milk will then be exactly similar in its properties to creamed or skimmed milk.

CAROLINE.

Yet butter-milk is very different from common skimmed milk.

MRS. B.

Because you know it is customary, in order to save time and labour, to make butter from cream alone. In this case, therefore, the butter-milk is deprived of the creamed milk, which contains both the curd and whey. Besides, in consequence of the milk remaining exposed to the atmosphere during the separation of the cream, the latter becomes more or less acid, as well as the butter-milk which it yields in churning.

EMILY.

Why should not the butter be equally acidified by oxygenation?

MRS. B.

Animal oil is not so easily acidified as the other ingredients of milk. Butter, therefore, though usually made of sour cream, is not sour itself, because the oily part of the cream had not been acidified. Butter, however, is susceptible of becoming acid by an excess of oxygen; it is then said to be rancid, and produces the sebacic acid, the same as that which is obtained from fat.

EMILY.

If that be the case, might not rancid butter be sweetened by mixing with it some substance that would take the acid from it?

MRS. B.

This idea was suggested by Sir H. Davy, who supposed, that if rancid butter were well washed in an alkaline solution, the alkali would separate the acid from the butter.

CAROLINE.

You said just now that unskimmed milk consisted of curd and whey. Pray, how are these separated?

MRS. B.

They may be separated by standing for a certain length of time exposed to the atmosphere; but this decomposition may be almost instantaneously effected by the chemical agency of a variety of substances. Alkalies, rennet*, and indeed al-

* Rennet is the name given to a watery infusion of the coats of the stomach of a sucking calf. Its remarkable effi-

most all animal substances, decompose milk by combining with the curda.

Acids and spirituous liquors, on the other hand, produce a decomposition by combining with the whey. In order, therefore, to obtain the whey pure, rennet, or alkaline substances, must be used to attract the curds from it.

But if it be wished to obtain the curds pure, the whey must be separated by acids, wine, or other spirituous liquors.

EMILY.

This is a very useful piece of information ; for I find white-wine whey, which I sometimes take when I have a cold, extremely heating ; now, if the whey were separated by means of an alkali instead of wine, it would not produce that effect.

MRS. B.

Perhaps not. But I would strenuously advise you not to place too much reliance on your slight chemical knowledge in medical matters. I do not know why whey is not separated from curd by rennet, or by an alkali, for the purpose which you mention : but I strongly suspect that there must be some good reason why the preparation by means of wine is generally preferred. I can, however, safely point out to you a method of obtaining whey without either alkali, rennet, or wine ; it is by sub-

cacy in promoting coagulation is supposed to depend on the gastric juice with which it is impregnated.

stituting lemon-juice, a very small quantity of which will separate it from the curds.

Whey, as an article of diet, is very wholesome, being remarkably light of digestion. But its effect, taken medicinally, is chiefly, I believe, to excite perspiration, by being drunk warm on going to bed.

From whey a substance may be obtained in crystals by evaporation, called *sugar of milk*. This substance is sweet to the taste, and in its composition is so analogous to common sugar, that it is susceptible of undergoing the vinous fermentation.

CAROLINE.

Why then is not wine, or alcohol, made from whey?

MRS. B.

The quantity of sugar contained in milk is so trifling, that it can hardly answer that purpose. I have heard of only one instance of its being used for the production of a spirituous liquor, and this is in Arabia: the abundance of horses, as well as the scarcity of fruits in that country, has introduced the fermentation of mares' milk, by which the Arabs produce a liquor called *koumiss*. Whey is likewise susceptible of being acidified by combining with oxygen from the atmosphere. It then produces the *lactic acid*, which you may recollect is classed with the animal acids as the acid of milk.

Let us now see what are the properties of casein or curd.

EMILY.

I know that it is made into cheese; but I have heard that for that purpose it is separated from the whey by rennet; and yet this, you have just told us, is not the method of obtaining pure curd.

MRS. B.

Nor is pure curd so well adapted for the formation of cheese. For the nature and flavour of the cheese depend, in a great measure, upon the cream or oily matter which is left in the curd; so that if every particle of cream be removed from the curd, the cheese is scarcely eatable. Rich cheeses, such as cream and Stilton cheeses, derive their excellence from the quantity, as well as the quality, of the cream which enters into their composition.

CAROLINE.

I had no idea that milk was such an interesting compound. In many respects there appears to me to be a very striking analogy between milk and the contents of an egg, both in regard to their nature and their use. They are each of them composed of the various substances necessary for the nourishment of the young animal, and equally destined for that purpose.

MRS. B.

There is, however, a very essential difference.

The young animal is formed, as well as nourished, by the contents of the egg-shell; whilst milk serves only as nutriment to the suckling after it is born.

There are several peculiar animal substances which do not enter into the general enumeration of animal compounds, and which, however, deserve to be mentioned.

Spermaceti is of this class; it is a kind of oily substance obtained from the head of the whale, which, however, must undergo a certain preparation before it is in a fit state to be made into candles. It is not much more combustible than tallow, but it is pleasanter to burn, as it is less fusible and less oily.

Ambergris is another peculiar substance derived from a species of whale. It is, however, seldom obtained from the animal itself, but is generally found floating on the surface of the sea.

Wax, you know, is a concrete oil, the peculiar product of the bee, part of the constituents of which may probably be derived from flowers, but so prepared by the organs of the bee, and so mixed with its own substance, as to be decidedly an animal product. Bees' wax is naturally of a yellow colour, but it is bleached by long exposure to the atmosphere, or may be instantaneously whitened by chlorine. The combustion of wax is far more perfect than that of tallow, and consequently produces a greater quantity of light and heat.

Lac is a substance very similar to wax in the manner of its formation; it is the product of an insect, which collects its ingredients from flowers, apparently for the purpose of protecting its eggs from injury. It is formed into cells, fabricated with as much skill as those of the honey-comb, but differently arranged. The principal use of lac is in the manufacture of sealing-wax, and in making varnish and lackers.

Musk, *civet*, and *castor*, are other particular productions, from different species of quadrupeds. The first two are very powerful perfumes; the latter has a nauseous smell and taste, and is only used medicinally.

CAROLINE.

Is it from this substance that castor oil is obtained?

MRS. B.

No. Far from it; for castor oil is a vegetable oil, expressed from the seeds of a particular plant, and has not the least resemblance to the medicinal substance obtained from the castor.

Silk is a peculiar secretion of the silk-worm, with which it builds its nest or cocoon. This insect was originally brought to Europe from China. Silk, in its chemical nature, is very similar to the hair and wool of animals; whilst in the insect it is a fluid which is coagulated, apparently by uniting with oxygen, as soon as it comes in contact with the air. The moth of the silk-worm

ejects a liquor which appears to contain a peculiar acid, called *bombic acid*, the properties of which are but very little known.

EMILY.

Before we conclude the subject of the animal economy, shall we not learn by what steps dead animals return to their elementary state?

MRS. B.

Animal matter, although the most complicated of all animal substances, returns to its elementary state by one single spontaneous process, the *putrid fermentation*. By this, the albumen, fibrine, &c. are slowly reduced to the state of oxygen, hydrogen, nitrogen, and carbon; and thus the circle of changes through which these principles have passed is finally completed. They first quitted their elementary form, or their combination with unorganised matter, to enter into the vegetable system. Hence they were transmitted to the animal kingdom; and from this they return again to their primitive simplicity, soon to re-enter the sphere of organised existence.

When all the circumstances necessary to produce fermentation do not take place, animal, like vegetable, matter is liable to a partial or imperfect decomposition, which converts it into a combustible substance very like spermaceti. I dare say that you, Caroline, who are so fond of analogies, will consider this as a kind of animal bitumen.

CAROLINE.

And why should I not, since the processes which produce these substances are so similar ?

MRS. B.

There is, however, one considerable difference; the state of bitumen seems permanent, whilst that of animal substances, thus imperfectly decomposed, is only transient; and unless precautions be taken to preserve them in that state, a total dissolution infallibly ensues. A manufacture was established near Bristol, in which, by exposing the carcasses of horses and other animals for a length of time under water, the muscular parts were converted into this spermaceti-like substance. But the attempt has been relinquished, as it was found impracticable to purify it sufficiently to make it useful.

Thus art contrives to enlarge the sphere of useful purposes, for which the elements were intended by nature; and the productions of the several kingdoms are frequently arrested in their course, and variously modified, by human skill, which compels them to contribute, under new forms, to the necessities or luxuries of man.

But all that we enjoy, whether produced by the spontaneous operations of nature or the ingenious efforts of art, proceed alike from the goodness of Providence.—To GOD alone man owes the admirable faculties which enable him to improve and

modify the productions of nature, no less than those productions themselves. In contemplating the works of the creation, or studying the inventions of art, let us, therefore, never forget the Divine source from which they proceed : and thus every acquisition of knowledge will prove a lesson of piety and virtue.



INDEX.

A.

ABSORBENT vessels, ii. 321.
Absorption of caloric, i. 57. 63.
 ——— of vegetable sap, 278.
Acetic acid, ii. 75. 192.
Acetous fermentation, ii. 228.
 ——— acid, ii. 228.
Acids, i. 263 ; ii. 70.
Acidulous mineral waters, ii. 127.
 ——— salts, ii. 195.
Aëriform, i. 36.
Affinity, i. 22 ; ii. 1.
Agate, ii. 54.
Agriculture, ii. 241. 249. 272.
Air, i. 191 ; ii. 253.
Air-vessels, ii. 349.
Albumen, ii. 296. 306.
Albumum, ii. 284.
Alchemists, i. 4.
Alcohol, or spirit of wine, ii. 211. 217. 230.
Alembic, i. 259.
Alkalies, ii. 25.
Alkaline earths, ii. 54. 61.
Alloys, i. 340.
Alum, or sulphate of alumine, ii. 58. 98.
Alumine, ii. 48. 57.
Aluminium, i. 15.
Amalgam, i. 344.
Ambergria, ii. 375.
Amethyst, ii. 61.
Amianthus, ii. 68.
Ammonia, or volatile alkali, i. 361 ; ii. 25. 40.
Ammoniacal gas, ii. 41.
Ammonium, i. 14.

Analysis, i. 285.
 ——— of vegetables, ii. 160.
Animal acids, ii. 76. 308.
 ——— colours, ii. 310.
 ——— heat, ii. 354.
 ——— oil, ii. 175. 307.
Animalisation, ii. 295. 314. 330.
Animals, ii. 295.
Antidotes, ii. 45. 86.
Antimony, i. 18.
Aqua fortis, ii. 105.
 ——— regia, i. 337 ; ii. 139.
Argand's lamp, i. 214.
Aromatic woods, durability of, ii. 287.
Arrack, ii. 215.
Arsenic, i. 18. 337. 349.
Arsenical acid, ii. 75.
Arterial blood, ii. 320. 344.
Arteries, ii. 320. 340.
Asphaltum, ii. 235.
Assafoetida, ii. 184.
Assimilation, ii. 314.
Astringent principle, ii. 194.
Atmosphere, i. 83. 191. ; ii. 253.
Atmospherical air, i. 191.
Atomic theory, ii. 15.
Attraction of aggregation, or cohesion, i. 20 ; ii. 2.
 ——— of composition, i. 20 ; ii. 1.
Azote, or nitrogen, i. 191 ; ii. 101.
Azotic gas, i. 191.

B.

Balloons, i. 247.
Balsams, ii. 160. 184.

- Barium, i. 15.
 Bark, ii. 188. 282.
 Barytes, ii. 48. 61. 63.
 Basis of acids, i. 264; ii. 70.
 ——— gases, i. 193.
 ——— salts, ii. 4.
 Beer, ii. 207. 216.
 Beet-root sugar, ii. 165.
 Benzoic acid, ii. 75. 192.
 Bile, ii. 323.
 Birds, ii. 365.
 Bismuth, i. 18.
 Bitumens, ii. 235.
 Black-lead, or plumbago, i. 302.
 Bleaching, i. 32; ii. 89. 142.
 Blood, ii. 322. 334.
 Blood-vessels, ii. 315.
 Blow-pipe, i. 316; ii. 222.
 Boiling water, i. 92.
 Boletic acid, ii. 75. 192.
 Bombic acid, ii. 76. 308.
 Bones, ii. 315.
 Boracic acid, i. 363; ii. 74. 129.
 Boracium, i. 14; ii. 130.
 Borate of soda, ii. 131.
 Brain, effect of intoxication on,
 from recent experiments, ii.
 219.
 Brandy, ii. 214.
 Brass, i. 340.
 Bread, ii. 229.
 Breathing, ii. 335.
 Bricks, ii. 59.
 Brittle metals, i. 19.
 Brome, i. 12. 219; ii. 151.
 Bronze, i. 340.
 Butter, ii. 369.
 Butter-milk, ii. 370.

 C.
 Cadmium, i. 17.
 Calcareous earths, ii. 67.
 Calcareous stones, ii. 121.
 Calcium, i. 15.
 Caloric, i. 11. 68.
 Caloric, absorption of, i. 57. 64.
 ———, capacity for, i. 121.
 ———, combined, i. 119.
 ———, conductors of, i. 68.
 ———, equilibrium of, i. 50.
 ———, expansive power of, i.
 34.
 ———, radiation of, i. 51. 59.
 ———, reflection of, i. 53. 64.
 ———, solvent power of, i. 93.
 98.
 Calorimeter, i. 148.
 Calx, i. 204.
 Camphor, ii. 160. 181.
 Camphoric acid, ii. 75. 192.
 Caoutchouc, ii. 160. 184.
 Carbon, i. 281; ii. 355.
 Carbonate of ammonia, ii. 45.
 ——— lead, i. 314.
 ——— lime, ii. 64. 119.
 ——— magnesia, ii. 67.
 ——— potash, ii. 28. 31.
 Carbonated hydrogen gas, i.
 299.
 Carbonates, ii. 31. 127.
 Carbonic acid, i. 191. 290. 358;
 ii. 74. 344.
 ——— gas, i. 287.
 Carburet of iron, i. 302.
 Carburets, i. 338.
 Carmine, ii. 312.
 Cartilage, ii. 319.
 Caseic acid, ii. 76. 308.
 Casein, ii. 308.
 Castor, ii. 376.
 Caustics, i. 348.
 Cellular membrane, ii. 326.
 Cerium, i. 19.
 Cetic acid, ii. 76. 308.
 Chalk, ii. 64. 121.
 Champagne, ii. 213.
 Charcoal, i. 281.
 Cheese, ii. 374.
 Chemical atoms, ii. 15.
 ——— attraction, i. 20; ii. 8.
 Chemistry, i. 13.
 Chest, ii. 336.

- China, ii. 59.
 Chlorate of potash, ii. 146.
 Chlorates, ii. 145.
 Chlorine, i. 12. 219. 264; ii. 137.
 ———, protoxide of, ii. 143.
 Chrome, i. 18. 337.
 Chyle, ii. 322. 334.
 Chyme, ii. 334.
 Circulation of the blood, ii. 340.
 Citric acid, ii. 75. 192.
 Civet, ii. 376.
 Clay, i. 46; ii. 57.
 Coal, ii. 236.
 Cobalt, i. 18.
 Cochineal, ii. 312.
 Cold, i. 49. 56.
 ———, from evaporation, i. 98. 109. 142.
 Colours of metallic oxides, i. 314.
 Columbium, i. 18. 337. 347.
 Combined caloric, i. 117.
 Combustion, i. 194.
 ———, volatile products of, i. 213.
 ———, fixed products of, i. 213.
 ——— of alcohol, ii. 221.
 ——— of ammoniacal gas, ii. 46.
 ——— of boracium, ii. 130.
 ——— of candles, i. 241; ii. 173.
 ———, of carbon, i. 287.
 ——— of charcoal by nitric acid, ii. 103.
 ——— of coals, i. 213. 300.
 ——— of diamonds, i. 290.
 ——— of ether, ii. 225.
 ——— of hydrogen, i. 232. 237. 248.
 ——— of iron, i. 302. 317.
 ——— of metals, i. 312.
 ——— of oils, i. 214. 304; ii. 173.
 Combustion of oil of turpentine by nitrous acid, ii. 6.
 ——— by oxymuriatic acid, or chlorine, ii. 137.
 ——— of phosphorus, i. 272.
 ——— of potassium, i. 355; ii. 130. 135. 136.
 ——— of sulphur, i. 259.
 Composition of animals, ii. 295.
 ——— of vegetables, ii. 157.
 Compound bodies, i. 9; ii. 15.
 ———, or neutral salts, i. 325; ii. 3. 28. 70.
 Condensation of gases, ii. 152. 156.
 Conductors, Count Rumford's theory, i. 76—81.
 ——— of fluids, i. 76.
 ——— heat, i. 68.
 Constituent parts, i. 8.
 Copal, ii. 183. 220.
 Copper, i. 17. 333.
 Cortical layers, ii. 282. 284.
 Cotyledons, or lobes, ii. 275.
 Cream, ii. 369.
 ——— of tartar, or tartrate of potash, ii. 217.
 Cryophorus, i. 147.
 Crystallisation, i. 335; ii. 51.
 Cucurbit, i. 259.
 Culinary heat, i. 87.
 Curd, ii. 369.
 Cuticle, or epidermis, ii. 326.
 Cyanogen, i. 192; ii. 310.
- D.
- Davy's, Sir Humphry, safety-lamp, i. 251—256.
 Deamorphism, ii. 17.
 Decomposition, i. 7. 24.
 ——— of atmospherical air, i. 193. 215.
 ——— of salts by the Voltaic battery, ii. 21.

Decomposition of water by the
Voltaic battery, i. 225.

_____ of water by met-
als, i. 228. 327.

_____ by car-
bon, i. 298.

_____ of vegetables, ii.
199.

_____ of potash, i. 355.

_____ of soda, i. 361.

_____ of ammonia, i.
361 ; ii. 47.

_____ of the boracic
acid, ii. 130.

_____ fluoric
acid, ii. 132.

_____ muri-
atic acid, ii. 134.

Definite proportions, ii. 13.

Deflagration, ii. 117.

Deliquescence, ii. 96.

Deoxygenation, i. 306.

Detonation, i. 232 ; ii. 115.

Deutoxide of chlorine, ii. 143.

Dew, i. 101.

Diamond, i. 284 ; ii. 50.

Diaphragm, ii. 337.

Digestion, ii. 333.

Dissolution of metals, i. 311.
331.

Distillation, i. 260 ; ii. 214.

_____ of red wine, ii. 214.

Divellent forces, ii. 11.

Division, i. 7.

Double elective attraction, ii. 8.

Dry rot, ii. 232.

Drying oils, ii. 178.

Dyeing, ii. 186.

Dyes, ii. 186.

E.

Earthenware, ii. 56. 59.

Earths, ii. 25. 48.

Effervescence, i. 296

Efflorescence, ii. 95.

Elastic fluids, i. 36. 48.

Elective attractions, ii. 8.

Electrical machine, i. 181—186.

Electricity, i. 11. 175. 225.

_____, its influence on
magnetism, i. 187 ; on vege-
tation, ii. 293.

Electro-magnetism, i. 187.

Electrum, ii. 236.

Elementary bodies, i. 7. 11.

Elixirs, tinctures, or quinte-
sences, ii. 221.

Enamel, ii. 60.

Epidermis of vegetables, ii.
282.

_____ of animals, ii. 326.

Epsom salts, ii. 68. 96.

Equilibrium of caloric, i. 49.

Essences, ii. 179. 220.

Essential, or volatile, oils, ii.
172. 179.

Ether, i. 108 ; ii. 224.

Euchlorine, ii. 143.

Eudiometer, i. 276.

Evaporation, i. 99.

Evergreens, ii. 292.

Expansion of caloric, i. 35.

Extractive colouring matter, ii.
160. 186.

F.

Falling stones, i. 339.

Faraday, Mr., his condensation
of gas by pressure, i. 191.

_____, his recent expe-
riments on light, &c., ii. 293.

Fat, i. 304.

Feathers, ii. 316.

Fermentation, ii. 202. 274.

_____, the acetous, ii.
228.

_____, the putrid, ii.
230.

_____, the saccharine,
ii. 205. 275.

- Fermentation, the vinous, ii. 208.
 Fibrine, ii. 296. 307.
 Fire, i. 7. 28.
 Fire-damp, i. 251.
 Fish, ii. 364.
 Fixed air, or carbonic acid, i. 289; ii. 118. 213.
 — alkalies, ii. 25.
 — oils, ii. 160. 171.
 — products of combustion, i. 213.
 Flame, i. 239.
 Flint, ii. 35. 54.
 Flower or blossom, ii. 288.
 Fowers of sulphur, ii. 258.
 Fluor, ii. 133.
 Fluoric acid, i. 363; ii. 57. 74. 131.
 Fluorium, or Fluorine, i. 12. 219; ii. 133.
 Forces of attraction, ii. 9.
 Formic acid, ii. 76. 308.
 Fossil-wood, ii. 237.
 Frankincense, ii. 183.
 Free or radiant caloric, or heat of temperature, i. 33.
 Freezing mixtures, i. 42.
 —, by evaporation, i. 98. 142—150.
 Frost, i. 98.
 Fruit, ii. 288.
 Fuller's earth, ii. 58.
 Furnace, i. 302.

 G.
 Gallat of iron, ii. 98.
 Gallic acid, ii. 75. 192.
 Galls, ii. 194.
 Galvanism, i. 179.
 Gas, i. 191.
 Gases, condensed by pressure, i. 192.
 Gaseous mineral waters, ii. 127.
 — nitrogen, ii. 111.
 — oxide of carbon, i. 294.
 Gas-lights, i. 242.
 Gastric juice, ii. 333.
 Gelatine or jelly, ii. 296. 299—306.
 Germination, ii. 274.
 Gilding, by mercury, i. 344.; by oxide of gold, 344.; and by electricity, 344.
 Gin, ii. 216.
 Glands, ii. 315. 323.
 Glass, ii. 35.
 Glauber salts, or sulphate of soda, ii. 94.
 Glazing, ii. 60.
 Glucina, ii. 48.
 Glucinium, i. 15.
 Glue, 299.
 Gluten, ii. 160. 171.
 Gold, i. 17. 321.
 Guano, ii. 258.
 Gum, ii. 160. 275.
 — arabic, ii. 165.
 — elastic, or caoutchouc, ii. 184.
 —, resins, ii. 160. 182.
 Gunpowder, ii. 115.
 Gypsum, or plaster of Paris, or sulphate of lime, ii. 96.

 H.
 Hair, ii. 316.
 Harrowgate water, i. 269. 338.
 Hartshorn, ii. 40. 44. 301.
 Heart, ii. 340.
 Heart-wood, ii. 285.
 Heat, i. 11. 27. 33.
 — of capacity, i. 121. 199.
 — of temperature, i. 33.
 History of vegetation, ii. 272.
 Honey, ii. 170.
 Horns, ii. 300. 316.
 Humus, ii. 246.
 Hydro-bromic acid, ii. 152.
 Hydro-carbonate, i. 240. 251. 300.
 Hydro-chloric acid, ii. 143.
 Hydro-fluoric acid, ii. 133.

Hydrogen, i. 13. 217.
 ——— gas, i. 220. 237.

I and J.

Jasper, ii. 54.
 Ice, i. 130.
 Jelly, ii. 299.
 Jet, ii. 236.
 Ignes-fatui, i. 277.
 Ignition, i. 112.
 Imponderable agents, i. 11.
 Inflammable air, i. 220.
 Ink, ii. 98. 193.
 Insects, ii. 367.
 Integument parts, i. 8.
 Iodine, i. 12. 219 ; ii. 149.
 Iridium, i. 18. 345.
 Iron, i. 17. 313. 327.
 Isinglass, ii. 189. 299.
 Isomerism, ii. 17.
 Ivory black, ii. 312.

K.

Kali, ii. 39.
 Kinic acid, ii. 75. 192.
 Koumiss, ii. 373.

L.

Lac, ii. 376.
 Lactic acid, ii. 76. 308. 373.
 Lakes, colours, ii. 186.
 Lamp without flame, i. 323.
 Latent heat, i. 128.
 Lavender-water, ii. 180. 220.
 Lead, i. 17. 311. 328.
 Leather, ii. 188. 305.
 Leaves, ii. 276.
 Life, ii. 158. 162.
 Ligaments, ii. 319.
 Light, i. 11. 27 ; ii. 279. 293.
 Lightning, i. 249.
 Lime, ii. 48. 61.
 ——— water, ii. 63.
 Lime-stone, ii. 61.

Linseed-oil, ii. 175.
 Liqueurs, ii. 220.
 Litharge, i. 314.
 Lithic acid, ii. 76.
 Lithion, ii. 226.
 Lithium, i. 14.
 Liver, ii. 324.
 Lobes of vegetables, ii. 275.
 ——— of animals, ii. 350.
 Lunar caustic, or nitrate of silver, i. 348 ; ii. 118.
 Lungs, ii. 335. 343.
 Lymph, ii. 321.
 Lymphatic vessels, ii. 315. 321.

M.

Magnesia, ii. 48. 67.
 Magnesium, i. 15.
 Magnetic needle, i. 187.
 Magnetism, influence of electricity on, i. 187.
 Malic acid, ii. 75. 192.
 Malleable metals, i. 17.
 Malt, ii. 207.
 Manganese, i. 18. 312.
 Manna, ii. 170.
 Manure, ii. 240.
 Marble, ii. 121.
 Margaritic acid, ii. 76. 308.
 Marine acid, or muriatic acid, ii. 133.
 Mastic, ii. 183. 220.
 Materials of animals, ii. 296.
 ——— of vegetables, ii. 160.
 Mercury, i. 17. 136.
 ———, new mode of freezing, i. 148. 343.
 Metallic acids, i. 332.
 ——— oxides, i. 312.
 Metals, i. 17. 308.
 ———, dissolution of, i. 316.
 ———, electrical agency of, i. 179.
 ———, incandescence of, by hydrogen gas, i. 324.
 Meteoric stones, i. 339.

Mica, ii. 68.
 Milk, ii. 316. 322. 368.
 Milky juice in vegetables, ii. 286.
 Minerals, i. 310 ; ii. 50.
 Mineral acids, ii. 79.
 ——— waters, i. 295 ; ii. 127.
 Miner's lamp, i. 251.
 Mixture, i. 96.
 Molybdenic acid, ii. 74.
 Molybdenum, i. 18. 337.
 Mordant, ii. 152. 187.
 Moroxalic acid, ii. 75. 192.
 Mortar, ii. 56. 67.
 Mucilage, ii. 160. 164. 282.
 Mucous acid, ii. 75. 165. 192.
 ——— membrane, ii. 326.
 Muriate of ammonia, ii. 40. 144.
 ——— lime, i. 138.
 ——— soda, or common salt, ii. 133. 143.
 ——— potash, ii. 135.
 Murates, ii. 143.
 Muriatic acid, or marine acid, i. 363 ; ii. 74. 133.
 Muscles of animals, ii. 315. 319.
 Musk, ii. 376.
 Myrrh, ii. 184.

N.

Naphtha, i. 355 ; ii. 235.
 Native vegetable alkalies, ii. 196.
 Nature, laws of, ii. 281.
 Negative electricity, i. 177.
 Nerves, ii. 298. 315. 326.
 Neutral, or compound, salts, i. 331 ; ii. 3. 28. 70.
 Nickel, i. 17. 339.
 Nitrate of copper, ii. 5.
 ——— ammonia, ii. 112. 117.
 ——— potash, or nitre, or saltpetre, ii. 38. 105. 115.
 ——— silver, or lunar caustic, ii. 118.
 Nitrates, ii. 115.

Nitre, or nitrate of potash, or saltpetre, ii. 38. 105. 115.
 Nitric acid, ii. 74. 101.
 Nitrogen, or azote, i. 191 ; ii. 101.
 ——— gas, i. 192. 218.
 Nitro-muriatic acid, or aqua regia, i. 337 ; ii. 139.
 Nitrous acid gas, ii. 102. 107.
 ——— air, or nitric oxide gas, i. 192 ; ii. 107.
 Nomenclature of acids, i. 5. 9 ; ii. 70.
 ——— of compound salts, ii. 4. 28.
 ——— of other binary compounds, i. 277.
 Nut-gall, ii. 99. 194.
 Nut-oil, ii. 175.
 Nutrition, ii. 314.
 Nutritive secretions, ii. 324.

O.

Ochres, i. 314.
 Oil of amber, ii. 236.
 ——— vitriol, or sulphuric acid, ii. 80.
 Oils, i. 304 ; ii. 171.
 Oleic acid, ii. 76. 308.
 Olive oil, ii. 175.
 Ores, i. 311.
 Organisation, ii. 157.
 Organised bodies, ii. 157.
 Organs of animals, ii. 315. 326.
 ——— vegetables, ii. 163. 280. 288.
 Osmium, i. 18. 347.
 Oxalic acid, ii. 75. 192.
 Oxide of manganese, i. 312.
 ——— iron, i. 208. 313.
 ——— lead, i. 311. 314.
 ——— sulphur, ii. 93.
 Oxides, i. 205.
 Oxidation, or oxigenation, i. 205.
 Oxygen, i. 10. 190. 205.

- Oxygen gas, or vital air, i. 191.
209.
Oxymuriatic acid, ii. 136.
- P.
- Palladium, i. 17. 347.
Papin's digester, i. 115 ; ii. 302.
Parenchyma, ii. 275. 282. 284.
Particles, i. 20.
Pearl-ash, ii. 30.
Peat, ii. 237.
Peculiar juice of plants, ii. 286.
Perchlorates, ii. 143.
Perfect metals, i. 17. 321.
Perfumes, ii. 179.
Perkins', Mr., experiments for
condensing air, i. 192.
Perspiration, ii. 352. 357.
Petrification, ii. 233.
Pewter, i. 341.
Pharmacy, i. 4.
Phosphate of lime, ii. 100. 315.
Phosphorescence, i. 30.
Phosphoret of lime, i. 278. 338.
—— sulphur, i. 278.
338.
Phosphorets, i. 338.
Phosphoretted hydrogen gas,
i. 277.
Phosphoric acid, i. 273 ; ii. 74.
99.
Phosphorous acid, i. 274 ; ii.
99.
Phosphorus, i. 270.
Pitch, ii. 183.
Plaster, ii. 67.
Platina, i. 17. 319. 337.
—— ignited by a lamp with-
out flame ; Mr. Dobereiner's
experiment, i. 324.
Plating, i. 342.
Plumbago, or black-lead, i. 302.
Plumula, ii. 275.
Pole, positive, i. 183.
——, negative, i. 183.
Porcelain, ii. 59.
- Positive electricity, i. 177.
Potash, i. 355 ; ii. 25.
Potassium, i. 14. 356 ; ii. 26.
Pottery, ii. 59.
Precipitate, i. 25.
Pressure of the atmosphere, i.
108. 112. 154.
Printers' ink, ii. 142.
Protoxide of chlorine, ii. 143.
Prussian blue, or prussiate of
iron, ii. 274. 276.
Prussiate of iron, or Prussian
blue, ii. 310—312.
—— potash, ii. 309.
Prussic acid, ii. 76. 310.
Putrid fermentation, ii. 230. 377.
Pyrites, i. 338 ; ii. 97.
Pyro-citric acid, ii. 75. 192.
Pyro-malic acid, ii. 75. 192.
Pyrometer, i. 37. 46.
Pyro-tartaric acid, ii. 75. 192.
- Q.
- Quicklime, ii. 62.
Quiescent forces, ii. 11.
Quintessences, ii. 221.
- R.
- Radiation of caloric, i. 51.
—— Prevost's theory.
i. 50.
—— Pictet's explana-
tions, i. 53.
—— Leslie's illustra-
tions, i. 59.
Radicals, ii. 4. 70.
Radicule, or root, ii. 275.
Rain, i. 99.
Rancidity, ii. 178.
Rectification, ii. 218.
Reflection of caloric, i. 51. 65.
Reptiles, ii. 366.
Resinous electricity, i. 177.
Resins, ii. 160. 182. 282.
Respiration, ii. 335. 343.

Revival of metals, i. 326.
 Rhodium, i. 18. 347.
 Roasting metals, i. 311.
 Rock crystals, ii. 55.
 Ruby, ii. 61,
 Rum, ii. 215.
 Rust, i. 318. 327.

S.

Saccharine fermentation, ii. 205.
 Safety-lamp, i. 254—256.
 Sal ammoniac, or muriate of ammonia, ii. 40.
 ——— volatile, or carbonate of ammonia, ii. 45.
 Salifiable bases, ii. 4.
 Salifying principles, ii. 4.
 Saliva, ii. 323.
 Salt, ii. 93.
 Saltpetre, or nitre, or nitrate of potash, ii. 38. 105. 115.
 Sand, ii. 35. 54.
 Sandstone, ii. 54.
 Sap of plants, ii. 160. 163. 278. 280. 285. 287.
 Sapphire, ii. 61.
 Saturation, i. 97.
 Scorix, i. 312.
 Seas, temperature of, i. 82.
 Sebacic acid, ii. 76. 178. 308. 371.
 Secretions, ii. 323.
 Seeds of plants, ii. 206. 288. 293.
 Seed-leaves, ii. 276.
 Selenium, i. 18. 347.
 Seltzer water, i. 295; ii. 65. 127.
 Senses, ii. 325.
 Silex, or silica, ii. 48. 54, 55. 283.
 Silicate of potash, ii. 283.
 Silicium, i. 15.
 Silk, ii. 376.
 Silver, i. 17. 319.
 Simple bodies, i. 9—11.
 ——— elective attraction, ii. 8.

Size, ii. 299.
 Skin, ii. 188. 298. 326.
 Slaking of lime, i. 139; ii. 62.
 Slate, ii. 68.
 Smelting metals, i. 311.
 Smoke, i. 213.
 Soap, ii. 30.
 Soda, i. 361; ii. 25. 39.
 ——— water, i. 297.
 Sodium, i. 14. 361.
 Soils, ii. 240—252. 257. 268.
 Soldering, i. 342.
 Solubility, ii. 94.
 Solution, i. 93.
 ——— by the air, i. 98.
 ——— of potash, ii. 34.
 Specific heat, i. 121.
 Spermaceti, ii. 375.
 Spirits, ii. 219.
 Starch, ii. 160. 170.
 Starch-sugar, ii. 166.
 Steam, i. 133. 191.
 Steam-engine, i. 152.
 ———, its application to boats and land carriages, i. 152. 172.
 ——— general advantages, i. 172.
 ———, high pressure, i. 169.
 ———, Savary's and Newcomen's, i. 155.
 ———, Watt's double engine, with the latest improvements, i. 157.
 ——— boiler, i. 158.
 ——— cylinder, i. 158.
 ——— piston, i. 158.
 ——— steam box, i. 159.
 ——— sliding valves, i. 160.
 ——— throttle-valve, i. 166.
 ——— regulator, or governor, i. 167, 168.
 ——— fly wheel, i. 165.
 ——— condenser, i. 157. 160.

- Steam-engine lever, i. 155. 164.
 ——— air-pump, i. 163.
 ——— forcing pump, i. 163.
 ——— parallel motion, i. 169.
 ———, Wolfe's engine, i. 171. Why called a double engine, i. 172.
 ———, Marquis of Worcester's, i. 155.
 Steel, i. 303.
 Stomach, ii. 333.
 Stomates, ii. 253.
 Stones, ii. 50.
 Strontites, ii. 48. 69.
 Strontium, i. 15.
 Stucco, ii. 67.
 Suberic acid, ii. 75. 192.
 Sublimation, i. 258.
 Succin, or yellow amber, ii. 236.
 Succinic acid, ii. 75. 192. 236.
 Sugar, ii. 160. 169. 205.
 ——— of milk, ii. 373.
 Sulphate of alumine, or alum, ii. 58. 96.
 ——— barytes, ii. 61.
 ——— iron, ii. 4. 97.
 ——— lime or gypsum, or plaster of Paris, ii. 96.
 ——— magnesia, or Epsom salts, ii. 68. 96.
 ——— potash, ii. 93.
 ——— soda, or Glauber's salts, ii. 94.
 Sulphates, ii. 96.
 Sulphite of potash, ii. 5.
 ——— of ammonia, ii. 5.
 Sulphur, i. 257.
 ———, flowers of, i. 258.
 Sulphurets, i. 338.
 Sulphuretted hydrogen gas, i. 191; ii. 307.
 Sulphuric acid, i. 266; ii. 74. 80. 85.
 Sulphurous acid, i. 191. 264; ii. 86.
 Superoxygenated sulphuric acid, ii. 71.
 Sympathetic ink, i. 352.
 Synthesis, i. 285.
 T.
 Tan, ii. 188.
 Tannin, ii. 160. 188.
 Tantalum, i. 347.
 Tar, ii. 183.
 Tartaric acid, ii. 75. 192.
 Tartrate of potash, ii. 192.
 Tears, ii. 298. 323.
 Teeth, ii. 316.
 Tellurium, i. 18.
 Temperature, i. 33.
 Thaw, i. 149.
 Thermometers, i. 39.
 ———, Fahrenheit's, i. 41.
 ———, Réaumur's, i. 41.
 ———, centigrade, i. 2.
 ———, air, i. 43.
 ———, differential, i. 44.
 Thorinium, i. 15.
 Thunder, i. 249.
 Tin, i. 17. 318.
 Tinctures, ii. 221.
 Titanium, i. 18. 346.
 Turf, ii. 237.
 Turpentine, ii. 183.
 Transparency of bodies, ii. 35.
 Transpiration of plants, ii. 278.
 Tungsten, i. 18. 337.
 Tungstenic acid, ii. 74.
 U and V.
 Vaporization, i. 99.
 Vapour, i. 36. 47. 91. 191.
 Varnishes, ii. 183.
 Vegetable acids, i. 305; ii. 74. 160. 192.

- Vegetable colours, ii. 186.
 ——— heat, ii. 162. 290.
 ——— kingdom, ii. 238.
 ——— mould, ii. 246.
 ——— oils, ii. 171. 175.
 ——— oxides, i. 305.
 Vegetables, ii. 157.
 Veins, ii. 320. 340.
 Venous blood, ii. 321. 341. 355.
 Ventricles, ii. 342.
 Verdigris, i. 351.
 Vessels, lymphatic, ii. 321.
 Vinegar, ii. 228.
 Vinous fermentation, ii. 208.
 Vital air, or oxygen gas, i. 193.
 Vitreous electricity, i. 177.
 Vitriol, or sulphate of iron, ii. 80.
 Volatile alkali, i. 361; ii. 26.
 ——— oils, ii. 172. 179. 286.
 ——— products of combustion, i. 213.
 Voltaic battery, i. 180--189. 225. 321; ii. 21.
 Uranium, i. 28.
- W.**
- Water, i. 220; ii. 280.
 Water, decomposition of, by electricity, i. 225.
 ———, condensation of, i. 79.
 ——— of the sea, i. 82.
 ———, boiling, i. 91.
 ———, solution by, i. 93.
 ——— of crystallisation, i. 335.
 Wax, ii. 173. 375.
 Whey, ii. 369.
 White lead, i. 314.
 White of eggs, ii. 167.
 Will-of-the-wisp, i. 277.
 Wine, ii. 208.
 Wood, ii. 284.
 Woody fibre, ii. 160. 191. 284.
 Wool, ii. 316.
- Y.**
- Yeast, ii. 229.
 Yellow amber, ii. 237.
 Yttria, ii. 48.
 Yttrium, i. 15.
- Z.**
- Zinc, i. 17.
 Zirconia, ii. 48.
 Zirconium, i. 15.
 Zoonic acid, ii. 76. 308.

THE END.

LONDON:
 SPOTTISWOODES and SHAW,
 New-street-Square.

DIRECTIONS TO THE BINDER.

VOL. I.

PLATE I.	to face page	37
II.	—	42
III.	—	53
IV.	—	109
V.	—	144
VI.	—	153
VII.	—	158
VIII.	—	160
IX.	—	180
X.	—	201
XI.	—	225
XII.	—	245
XIII.	—	255
XIV.	—	259
XV.	—	316

VOL. II.

XVI.	—	22
XVII.	—	214
XVIII.	—	275



1

